THE LATER STAGES OF APPRENTICE TRAINING.

Paper presented to the Institution, Southern Section, by E. L. Forge, B.Sc., A.M.I.P.E.

I HAVE been asked to continue the subject that I dealt with last session in a short paper on Apprentice Training, and I want to deal particularly to-night with the technical training of apprentices rather than the practical apprenticeship.

It is, to me, a very welcome sign of progress that so much attention is being focussed to-day on the training of the young engineer, because I consider that an output of well trained young men should be held of equal importance in any works with the output of finished manufactured articles of the highest quality. It is true that the manufactured articles are sold for money, which is a tangible return, and under the enlightened system under which we live, we are not allowed to sell apprentices (unless they are footballers' apprentices), but a low output of badly trained men will in the long run be as detrimental to the works as a low output of finished articles.

Practically all the published works and papers on the subject of apprentice training appear to me to deal with schemes put up and run very successfully by mammoth firms, and we all probably have read—and admired—the schemes run by such firms as Metropolitan Vickers in this country and Pratt & Whitney in the U.S.A., to take two outstanding examples.

These firms have large financial resources, enormous works and influence, and are quite capable, if necessary, of running their own College courses. What I would like to see is some co-ordinated scheme which will do the same thing for the smaller firms, such as we find in Southampton and district, whose output in the aggregate and whose efficiency are just as important to the nation at large. Obviously a firm only employing some 300—400 hands cannot expect to be able to provide such lavish equipment for, or devote so much time to their apprentices as one employing 10,000, and yet their need for efficiently trained staff is even greater, for their "passenger carrying" capacity is much less.

I would revert to the paper which I read last year in order to call to mind some of the headings under which the apprentices

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were therein grouped. Having discussed "What is the right type of boy," the third question put was "What can we do for him when found?" and it was decided that each boy would be found to fulfil one of the following conditions: (a) He will never make an engineer; (b) he will make a good craftsman; (c) he will graduate from craftsmanship to the higher grades. It is with (c) that we are particularly concerned to-night.

Making the rather wide assumption that the term "higher grades" covers anyone not actually working at his tools, we find that the grades we are going to consider include: Foremen and assistant foremen, inspectors, progress chasers, design draughtsmen, jig and tool draughtsmen, planning engineer's staff, viewers and checkers, research engineers, departmental or shop managers, works managers, and managing directors.

It is these men—actual or in prospect—for whom the three subjects to be considered to-night are concerned, viz.: Classes, institutions, and examinations. I propose therefore to ask and endeavour to answer these questions:—

"What do we teach these people?"
"What should we teach these people?"
"What do the institutions do for these people?"
"What might the Institutions do for these people?"
"What do the Examinations tell us about these people?"
"What can examinations tell us about them?"

It is obvious, to me at any rate, that the "higher grades" listed above fall into two distinct categories—practical and technical. On the practical side you have all shops staff and associated staffs, and on the technical side the drawing office and research staffs. In any works I think it will be found that the practical staff (if I may use that phrase without hurting the drawing office's feelings) outnumber the technical staff considerably. In one works under my notice there are some 30 foremen, 12 inspectors and jig and tool men—chasers, etc., make up another round dozen—say 60 all told. The technical or research requirements of these works are met by six draughtsmen and three juniors. A proportion of 60 to 9, or shall we say a good working majority of 6 to 1 and I am prepared to suggest that this proportion can be more or less substantiated in any engineering works of any size, with the possible exception of some aeroplane works doing a considerable amount of new designing and experimenting.

Unfortunately, to produce six practical men and one technical man, the educational facilities almost invariably comprise six technical subjects to one practical and the whole efforts of our

technical colleges seem directed towards turning out text book engineers.

On surveying a typical evening class syllabus one finds 90% of the boys are taking the following subjects: Applied mechanics, theory of machines, strength of materials, engineering drawing, and heat engines.

After the boy has assimilated—or attempted to assimilate—all the knowledge comprised under these headings, he is permitted to study metallurgy and workshop organisation, but the study (for the embryo foreman) of such an essential matter as industrial psychology is left to the enterprise of some such body as the Worker's Educational Association.

I think the reason for this state of affairs is not far to seek, and lies in the fact that the technical colleges are still catering for the works organisation of the beginning of the century, when a foreman was only distinguishable from his men by the fact that he wore a bowler hat and sometimes a collar, jigs were designed with a piece of chalk or the edge of the bench—organised viewing, planning, and chasing being non-existent—and the sole source of light in the darkness, the drawing office.

In those days the draughtsman did a lot more work outside his actual job, and was considered the only man worth any technical education, and it is this same brand of technical education that is still being widely offered to all and sundry.

I therefore suggest that the time is ripe for a complete survey of the basic principles of our technical education and I would like to see the South of England (for the sake of example) form a strong committee representative of Employers, University, and Institutions —to lay down a sort of British standard specification of engineering technical education.

Only the employers can say wherein they find their staff lacking. Only the university or the technical colleges can supply the necessary skilled teaching to remedy the deficit. Only the institutions can supply the stimulus, by modifying their examination schedules, because as long as A.M.I.Mech.E., or A.M.I.P.E. is a standard accepted by employers—so long will the educationists teach along those lines, and so long will the student follow, or endeavour to follow.

To take first the question of where the staff show a lack of training. I do not think any shop will be the worse if the foreman or progress chaser has never been taught anything about Rankin's cycle or Poisson's ratio, but I do think the quality of his output will go up if he has a sound knowledge of the metallurgical properties of the material he deals with.

Similarly the men will work contentedly under a foreman who is quite ignorant of what happens when a block of wood slides down an inclined plane on frictionless pullies, but they will work still more contentedly under a man with some knowledge of Industrial Psychology with its implied ability to handle men satisfactorily.

Would it not be possible, therefore, in our New British Standard specification for Education to allow for two branches of Education—practical and technical ? As the openings for the practical men are as we have seen some six to one, encourage the boys to take this side first and if they show they have the brains, transfer them later to the technical side.

I would not interfere with the present elementary evening classes—called variously J.1., J.2., T.1., T.2., etc., as they are a valuable testing ground or filter. It is the boy who passes through these who calls for our particular interest, and for him I would prescribe the following subjects.

Engineering Drawing.

This is essential if he is to be able to transmit his ideas, but I would urge a complete change. At present we do not teach drawing —we teach draughtsmanship. For this class I would forbid the use of the T square or set square and instead teach the boy to work with a piece of plain paper and a 6 in. rule. If he can sketch legibly and neatly—he will be able to draw properly.

Workshop Practice.

The class in this could well follow closely the syllabus required for Section B of the Graduateship Examination of the Institution of Production Engineers. The subjects outlined there are all essential to the man in touch with the shops output, viz : Modification of design to assist production, limit systems, gauges and gauging, machine tools and their uses, the design of cutting edges, feeds and speeds, sequence of operations. To this I would add use of pocket books, a general periodic review of any new machinery or process introduced in the engineering world.

Metallurgy.

The syllabus for this should be designed with the fact constantly in mind that the student wants to know something about metallurgy, not to start him off on a path of further research in a metallurgical laboratory, but to give him a better and more intelligent appreciation of the nature of the metals he will be called on to handle.

Actually, therefore, I suggest that the syllabus should include something of the Strength of Materials Syllabus as follows :—

How metals are obtained from ore, iron, steel, copper, tin, etc.

Brief review of methods of steel production.

Composition and nature of alloys, brass, bronze, etc.

Characteristics of steels, mild, cast, high tensile, tool, etc., strengths and uses.

Heat treatment, annealing, normalising and effects.

British Standard Specifications, meaning and uses.

Etching and photomicrographs, how to read them.

Testing of materials.

Industrial Pyschology.

Remembering that our student is not yet actually a foreman but still only eighteen years of age or so ! I consider the syllabus for this requires very careful planning, and should be left entirely to the aforementioned Committee of Employers and Educationists. The best way to settle it would be to hold several conferences at which the employers should be encouraged to state without reserve wherein they find their existing staffs lacking from the point of view of mental outlook on the job, relations with those under, parallel with and above them, and endeavour to establish a syllabus that will lead to a broader outlook on these matters.

Whether the resulting classes will be fairly named psychology, or would be better named ethics does not matter much, as long as the lecturer gets the subject matter over.

As a tentative suggestion I would put forward : Analysis of motives, behaviourism and types, mental reactions, relations of employers and employed, types of employment—fatigue and monotony, time and motion study, etc., the application of this to industrial life.

It may seem odd to find our old friend, time and motion study, under the heading of psychology, but the grouping is in my opinion logical, and the introduction of facts into the syllabus will persuade the student that he is really learning something with a practical application, and not merely studying life in the abstract. Although this teaching of psychology may sound non-practical, I feel sure that, properly taught, it may have more effect on the works generally than all the other subjects put together.

If any employer will analyse his shop troubles—if he has any—he will probably find that, as far as they can be traced to a supervisor, they have their roots in ignorance, slackness, or bad psychology.

You can sack a man for being slack or not knowing enough, but it is not so easy to sack him for being a bad psychologist, because that very fact may not be apparent on the surface.

Works Organisation and Administration.

If our student is of the right type he will very much appreciate an insight into the way in which his and other works are administered, provided that, once more, the class is kept along sound practical lines. In parenthesis I would like to know why the question of choosing a site for a factory is always given such prominence. Surely the number of occasions on which an engineer is faced with this problem in his life must be few, and it will probably be done by the directors anyway. Yet every Institution seems to think that its graduates ought to be thoroughly competent to build a new works and staff and equip it throughout. In any case it is largely a matter of common sense, which an engineer of sufficiently high rank to be allotted the task might be expected to possess.

I would suggest, however, that the syllabus under this head be closely examined for our purpose. It usually covers all the ground that a works manager should know, but the course of instruction that we are investigating is not designed to produce works managers by the classfull—at least not yet.

So much for the classes for the practical man. To summarise, we are going to attempt to do the following: Having picked him out as a likely candidate for promotion—we are going to enter him for classes which will teach him: Something more about the arts and crafts of his job (workshop practice), something more about the materials he will handle (metallurgy), something more about the men he will handle (psychology), something more about the secrets of how his works are run (works administration).

I suggest that the main value of this schedule will lie in the fact that the subjects chosen are not only useful but also of interest to any young engineer who wants to get on, and he will give to these classes what the psychologists call apperceptive attention, which means so much to the rate and permanency of assimilation.

I would once again emphasise that these are only tentative suggestions, and that it is essential that the full syllabus should be the result of the combined deliberations of the employers. It should also be remembered that there will be, in the normal course of events, three years to cover this ground, so that the second and third year programmes could be widened still further if necessary.

So much for the practical engineer. Let us now turn to the technical engineer—the man who is cut out for the drawing office, the research establishment or the laboratory.

I think we shall have made a good step forward along the road to 100% efficient personnel if we accept the theory that the shops man and the drawing office man have two separate and distinct individualities. All of you can probably recollect some case which has

come before you where a brilliant technical man has been made a works manager or works director, and has not been very successful in that capacity.

What, then, is required of the boy we send to the drawing office, or alternatively, will any chief draughtsman tell us wherein he finds the young men coming to him lacking ? For whilst we are reorganising education this evening we might as well reorganise completely.

My suggestion is that the following are essential : The complete strength of materials syllabus of the Institution of Mechanical Engineers with the considerable addition of the recognition of the fact that there are to-day other materials than iron and steel. The complete syllabus of theory of machines and machine design of the same Institution.

It is, I think, essential that our young draughtsman should have these subjects absolutely at his finger tips, and what else ? Engineering drawing—certainly, and I would like to see even the draughtsman share in a class designed to make a periodic review of the later methods of production.

I will give two examples. I find that few draughtsmen appreciate the possibilities of the oxy-acetylene flame cutting machine, or, to be more accurate, the possibility of the combination of this process with smithing for producing expensive forgings. Secondly many a " forging " is now produced by the flame cutter cutting out a plate—the smith bending it and the electric welder fastening it up to something else, but I look in vain for any course of instruction that will tell a draughtsman all about this. To-day the only chance a draughtsman has of keeping his designs in tune with modern production is the contact he makes with the irate production engineer who wants alterations made which should never have been necessary.

For the remainder I would allow the student to make his choice among the sub divisions of the I. Mech. E. syllabus, i.e., heat engines, hydraulics, internal combustion or aeronautics, by reference to the particular branch of engineering in which he is being trained and in which he hopes to earn his living.

Institutions.

We will now turn to the Institutions, whose name is legion. I frequently have to advise a young man whether to join an Institution and which institution to join.

We have of course what the daily press—if it knew anything about them—would unhesitatingly call " The Big Three "—the Mechanicals, the Civils, and the Electricals, but there are others.

A young man in the branch of the profession with which I am concerned has also The Institution of Locomotive Engineers,

The Institution of Production Engineers, to which he may become attached in addition.

If he comes to me for advice I have to tell him " Join the Institution of Mechanical Engineers, because, in the search for employment, membership of that body still counts—but don't expect them to help you as a locomotive engineer or a production engineer. If you really want to learn more about your job you must be a member of at least three institutions." The boy next asks what the subscriptions are, and gets rather a shock.

His next question to me takes the form of asking what he will get if he pays out these—to him—vast sums. The answer of " The Journal " is not particularly satisfactory. Permission to attend the meetings does not convey very much thrill to anyone who spends every leisure evening in the study of engineering, so that I feel my answer is rather unsatisfactory.

What should I like to be able to say ?

I should like to be able to tell him there exists for him one big Institution of Engineers under whose auspices he may learn by the spoken and written word about any branch covered by the title, without having to pay duplicate subscriptions.

I should like to be able to tell him that his continued membership of that institution would depend entirely on his continued satisfactory performance of his professional duties, so that the letters after his name are worth working for, and a real source of pride to their possessor.

I should like to be able to tell him that all engineering firms of repute draw their technical personnel entirely from the employment registers of this Super-Institution.

I should like to be able to tell him that no one has a chance of getting a really good job without working hard for membership of the body referred to.

I should like to be able to tell him that the doors of the Super-Institution would be open to the practical man just as much as the technical man, and he would not have to wait until he has got a good job before he can mount the letters after his name.

There are many other things I would like to be able to tell this boy, which perhaps are better left unsaid at this juncture, but my principal point is that in my opinion the big institutions do not exercise the power which lies latent in them by reason of their colossal memberships.

An ordinary works engineering society with which I am connected, runs a series of winter lectures, a series of summer visits, and a technical library of books. How much more does a big institution do ?

I suggest there might well be more grades in these institutions if their letters are to be the gauge by which we measure engineers. At present qualification in an Institution is only obtained by saying "What I have done," not "What I am capable of doing," in other words Associate Membership is given to a man who has got there, and is no help whatever to him in getting there, He has to do that as a Graduate, a rank which inevitably stamps him with the brand of extreme youth.

(In parenthesis I should like to make it clear that I am not endeavouring to single out one Institution from amongst its fellows for attack. They all seem to be tarred with the same brush.)

I have one more suggestion, and then we will leave the Institutions. I do not consider that the possession of the qualification they give should be dependent upon payment of annual subscriptions. An Institution qualification, once given, should be a permanent degree as much as any University degree.

Examinations.

I wonder how many fine engineers have gone through life unqualified because of the examination system. The question is "What do we want from examinations, and do we get it?"

The examination, we hope, is the yardstick by means of which we measure the boy's progress along the path of education, and the X-ray apparatus by which we peer into the boy's mind to see how much of the lecturers' teaching he has absorbed. But is it? I am afraid the answer is "sometimes."

If a boy comes out of a Heat Engines examination with 98% marks we still do not know whether: (a) He is a second Professor Rankin, or; (b) he simply has a capacious memory, or; (c) he has made a tremendous effort to mug up the stuff for the examination and will have forgotten all bar the odd 8% in six months time, or; (d) he had a capacious shirt cuff.

It seems to me obvious that to attempt to gauge in a three hours period what may have taken 100 hours to learn, is at the best a hit and miss affair.

However, we must have a yardstick of some kind or other, and I confess I am not prepared to advance any suggestion that would sweep all examinations away lock, stock, and barrel, though as an employer I should be much more influenced in reviewing a boy's technical career by noting his percentage attendance and homework marks rather than his examination marks. Surely if a boy attends regularly at a class, does all the homework required and gets a satisfactory report from his lecturer, that is as good a credential as any examination. Examinations are with us to-day and, like the poor, seem to be a permanency, so that we must make the best of them

and try to ensure that even they are an encouragement to a boy rather than a formidable stumbling block.

I think the trouble with examinations at the moment is that there are far too many of them, just as there are far too many Institutions. The Institution of Mechanical Engineers have a complete set of examinations which range largely over what we have earlier this evening called both the practical and technical side of Engineering Education. Running parallel with this we have the Institution of Production Engineers with also a complete range covering the practical side.

The Institution of Electrical Engineers again have a complete range covering the electrical side, but of course implying an application for membership by any person taking them.

I suggest the time has come for the whole matter to be handed over to some joint or central authority not for them to set standard examination papers (these might become too well known), but to lay down a set of standard syllabuses. Each institution could then state which standard syllabuses should be covered to qualify for each grade of membership, and the student would be free to direct his energies along the lines which best suited his developing personality and career.

When I last read a paper to you on this subject I was subsequently reproached in a writted communication, for trying to make things too easy for the apprentices and undermining those qualities of hard work and self-denial, the exercise of which go to produce the finest characters. That was because, as some of you may remember, I advocated the total abolition of evening classes. That comment came from a member of the Institution who has every right to speak with authority on the matter, and for whose judgement on the point I have every respect. This being the case I gave this matter a good deal of thought with the result, however, that I am afraid I find myself still unrepentant. I am sufficiently optimistic to think that just as we have to-day a superior type of man for a craftsman to that of thirty-five years ago, so the boy of to-day has a keener brain than his father of yesterday, and has more opportunity to fill his leisure time usefully.

Finally before I close, may I tell you one or two anecdotes which concern cases I have noted during the past few years, which have influenced the views that I have put before you. In self defence I would add that I regard these as outward expressions of recurrent cases and not as isolated instances.

A few years ago I had a young pupil working under me who came from abroad. He was quite the most helpless specimen I have yet encountered. He once spent a whole afternoon waiting for me to come back to the offices so that he could tell me that a new roll of tracing paper was not quite the same shade as the last

one, and to ask if he should use it. He was so hopeless that even my patience expired and I am afraid my comments on his work were frequently terse. On one occasion he said to me " I cannot understand why you are not satisfied with me, Mr. Forge. At college I was the most brilliant man of my class." He got the obvious retort.

Another young lad of my acquaintance, set his heart on passing a certain examination. He went to evening classes five nights a week, did homework on a sixth, and failed in the examination completely, yet he is quite a clever boy. Whose was the fault of the failure? His, or the examination system?

A third case was that of a young man with whom I worked at college. We worked together in class and in the various laboratories, and I have no hesitation in saying he was a far cleverer engineer than myself. I scraped a pass in the B.Sc. examination, he gained the first class College Diploma with distinction. He would very much have liked to have taken the B.Sc. too, but he failed his London Matriculation at school in French, so he could not possibly be an engineer.

And now to close may I put it on record that I have no sympathy with those who are always bewailing the decadence of the boy of to-day. I suspect this song has been sung to very much the same tune since Cain failed to hit it off with Abel (in another twenty years I shall probably be singing it myself), but at the moment I believe that in the better type of boy of to-day we have some very fine material indeed, and provided only that we train him properly in tune with the ever-changing modern conditions, the future of British engineering will be safe in his hands.

Discussion

Mr. Denny (Section President, who presided) said that they had listened to a very interesting paper and he congratulated Mr. Forge on the way he had prepared and given it. There was only one query he had to put, and that was to ask why Mr. Forge had introduced the subject of industrial psychology for an apprentice ?

Mr. Forge explained that a syllabus on industrial psychology would be an elementary one, The boy was not a grubby urchin just starting work ; he had been through the elementary classes and was probably somewhere about eighteen years of age, and that was about the time when a boy would absorb a syllabus of that nature. His mind had not become set, it was receptive, and it would not be too early to start a boy off on that particular subject.

Professor Cave-Browne-Cave said that he knew it was usually best that only the Chairman should say anything in appreciation of the lecturer because otherwise the subsequent speakers would begin in a similar manner and thus a great deal of time would be lost He was going to depart from custom because he was specially struck with the thoroughness and clearness with which Mr. Forge had put this difficult subject to them.

One excellent general point with which he agreed very strongly indeed, was that in deciding what should be taught to the apprentice after the end of his time, the practical engineers in industry should have more weight that the people teaching the apprentices. It was essential that the instruction in practical subjects, as apart from general theoretical principles, should be laid down in detail by the practising men as distinct from the professional instructors.

How was that to be done ? He thought that it was the Institutions, as representing the aggregate of professional engineering knowledge, who ought to get together and come to a fairly clear conclusion as to what apprentices and engineers should be taught after the completion of their apprenticeship in order to make them best fitted for their job. The Educational Committees or the Examination Committees of the institutions were not strong enough in practising men. That was not the fault of the professors, it was the fault of the professional members of the institutions who would not find time to do the constructive thinking which was necessary to let them give a representative opinion. It was however the institutions' job and you could not blame the professors if they had to do the best they could.

Much the same kind of thing applied to the difference between what Mr. Forge has called the " clerical principles " and the principles of practical subjects. He entirely agreed with him that there

was a great deal too much effort devoted to subjects such as those for the Engineering Degrees and for the Ordinary and particularly the Higher National Certificates. There was too much concentration upon subjects of the theoretical type. Far more attention ought to be given to the general subjects on which the practical work depended. Even in these practical subjects we must discriminate between those things which were best taught in classes at a college and those things which must necessarily be taught either in the shops or in special lectures arranged at the works by the people in those works. Reference had been made to Metropolitan Vickers. He had recently seen the syllabuses of the lectures which were to be given to apprentices, pupils and students in that firm after they had finished their courses and had gone to the works. Those works lectures given by the men in the works who were responsible for the application of those principles, constitutes exactly the kind of information which apprentices ought to have. They were much more convincing and much more comprehensible if they came from a man who was actually applying them to a real job than if they came second or third hand from a teacher at a technical college who had probably looked up somebody's textbook and perhaps had never seen the practical application at all. On the other hand the college teachers could best deal with general principles.

Industrial psychology. A very good subject, but a terrifying name. He thought they would all agree with Mr. Forge if he would wash out " industrial psychology " and teach exactly the same thing with a different name and no jargon. Why not call it " handling men " or " organisation " or " administration " ?

He thought what Mr. Forge had said about teaching works organisation was also very true. It was wasteful and perhaps detrimental to " teach the Subs the Admiral's job." It was bad for two reasons. First because the Subs were rather inclined to criticise the Admiral, and secondly because when they became Admirals they were apt to try and do the Admiral's job as they were taught it forty years before. So it was very much better to teach them just those principles of works organisation which they were likely to have to apply at the present time or within the next year or so. The technique of works organisation would change before they came into the position of works managers and managing directors.

Sketching as distinct from engineering drawing was most valuable. He wondered why simple marginal sketches were not more used to improve and clarify many verbal descriptions even of non engineering subjects.

Clear simple sketching and ability to verbalise from a drawing were for many students, far more important than dexterity in making beautiful drawings or than ability to make complicated projections.

The lecturer had outlined the subjects of the examinations which he thought were sound and had indicated those which he thought were less useful. He had also suggested one or two which should certainly be included. He did not mention two points, which were of great importance : the question of fatigue and the question of vibration. A surprisingly large proportion of failure are due to fatigue and much of it originates in vibration. But very little about these subjects appeared even in the degree syllabus. Practically no mention whatever was made about the comparatively simple principles which underlie vibration.

He agreed with Mr. Forge as to the defect of the examination scheme. Although the teacher who saw the work which a student did during his course, must be able to form a very good gauge of what that man's ability was, it was extremely difficult to define and correlate that judgment with the judgment of anybody else. There was a great deal to be said for the external examination as a fair and comparative test.

Years ago the national certificate in mechanical engineering was established in order to co-ordinate with some uniform minimum standard the certificates which were being issued to apprentices who had undergone technical training in a great variety of colleges. The system ensured that all certificates which were issued and described as national certificates were not certificates that a boy had passed a particular examination, but that he had followed an approved course and passed an examination both of which were up to a prescribed minimum standard. The national certificate examination of some colleges was a great deal higher than that of other institutions but they were all up to a specified minimum.

It was hard for a youngster who since the age of sixteen had done better in his technical work and his practical work than the boy alongside him, not to get a degree in engineering if he had failed in French or perhaps in geography. A degree and an Associate Membership Examination were rather different in character, but the main essential difference was that one examination insisted upon matriculation and the other one did not. Was matriculation more valuable for an engineer than certain of the subjects which the Associate Membership examinations included but the degree did not.

It might turn out that if the engineering institutions could establish a really representative schedule and standard of knowledge for their examinations the Associate Membership would come to have greater value than the degree.

Mr. Forge said that he would like to thank Professor Cave very much for his kind opening remarks. He quite agreed with him on the question of teaching certain subjects in the works themselves, and in the previous paper he had distinctly advocated it,

but he thought that even that could be done at the colleges if necessary, provided the right men were chosen for lecturing. If you wanted lecturers on workshop matters get a production engineer who had had recent works experience.

With regard to industrial psychology. The name had become very much under a cloud, but if only this subject of industrial psychology were taken up and more widely taught he thought it would probably live that down and become respected. Fatigue and vibration should, of course, be in any syllabus that claimed to be up to date.

He was interested to hear about the formation of the National Certificate. He had often wondered how the National Certificates came into being and what the reason for it was, and he was rather surprised to learn that they may be of very different standards. The custom here at this University was to coach the boys for the the National Certificates, and he believed they carried with them exemption from the Institution of Mechanical Engineers in certain subjects, and as the " adviser in chief " to their apprentices, when they came to him and said " Shall I work for the Lower National or shall I work for the Studentship direct" not knowing enough about the National Certificate, he had been rather at a loss how to advise them, and he was still not quite clear and would like Professor Cave's advice on what a boy should work for. Should he take the Lower National and obtain partial exemption, or should he make a beeline for the Studentship itself?

PROFESSOR CAVE said he could only answer in general terms. First of all, the high standard of the National Certificate. He thought the national certificate scheme was an excellent compromise because it meant that the word " National " did convey that it was up to a certain minimum, and the fact that it was a National Certificate obtained say at Southampton University College meant that it was up to the particularly high standard of Southampton. The question between the Studentship and the Higher National Certificate was this: if a boy was likely to be able ultimately to attain the standard of the Associate Membership, and as a general rule one could tell that fairly clearly, it was better that he should work for the Studentship and then the Associate Membership. If he was not likely to get that far it was better to take the Ordinary National Certificate because that was a rather more practical qualification than the Studentship and could of course be followed by the Higher National Certificate.

Students who could not manage the Ordinary National Certificate with reasonable promptness would probably do much better to take a " minor course " in the fundamental principles of the practical aspect of their trade.

MR. CANTELLO said that modern industry was lacking in specialists. How then did they propose to train apprentices to be specialists ? For example, suppose there were two or three hundred boys in a shop, and most of those boys were "cheap labour," how did they propose to make them into apprentices Modern industry was out to make money, and this was one of the methods by which the boys are used, as "cheap labour." Now where did they reckon to draw the line and make the boys apprentices ? If they made apprentices, how did they propose to get over the difficulty of specialists ?

MR. FORGE said that if you made the boys apprentices, in other words, gave them a definite indenture, he would suggest that they would be better able to pick the specialists if the basic foundation of education was general. He called to mind a case in his works where one of their apprentices had been trained. He was an extremely good fellow at that trade, he had done extremely well at the university classes here, and they felt that they had got to do something for that boy, but at the moment they did not know what to do with him because they had not got an opening for a specialist in that direction. The particular case in their works might be different, but as a matter of general principle, he thought that the boy would be better off, at any rate in his early years, with a general training. Then, if you picked him yourself as having a special aptitude for any specialised branch of engineering, it was up to you to direct his training in that branch, but when they had two hundred apprentices they would probably not have room for more than 5% out of that number for the higher grade jobs, and they should be able to pick that 5%. Probably out of that two hundred, 20% would be really worth technical education, and out of that 20% they could direct 5% into the specialised branches at the later stages.

MR. CANTELLO asked how Mr. Forge was going to select that 5%.

MR. FORGE considered it would be possible by having somebody at the works who was in touch with the boys. If that somebody was really in touch with them he thought it would be possible to do it with a fair margin of success.

MR. CANTELLO said that if you left it to one man to choose a boy or apprentice, surely any one man would be liable to be biased, and therefore you might find that a remarkably good boy was held back, although it is admitted that most employers have a man in this post who is known for his impartiality, but this may not be so in the smaller shops.

MR. FORGE said that in appointing one man in a firm to supervise the apprentices, the selection of that one man was perhaps the most critical job that the Works Manager would ever have to face. That one man would have to be exceptional and would hold the key to the

training. The present principle was usually to have one man responsible for apprentice supervision.

Mr. Townsley said it was very difficult to criticize such a paper, but there was one thing he would like to see introduced into the syllabus for the Higher Grade, and that was Company Law. He thought that it was a subject which came into a man's sphere when he reached a higher position, and in his experience they had very little opportunity to study Company Law. He considered that it was a subject which should be included.

He would like to refer to the discussion on dealing with boys, not in aircraft, but in shipbuilding. In his late firm they had as many as five hundred apprentices and there were two schemes of training—technical training and also a practical school of their own where the boys were taken in and put under experts in the trade to learn the practical side. Watching this for a number of years it was rather remarkable to see the number of those boys who gained executive positions. The majority of them were not the boys who had gone to Technical Colleges at night, but those who had actually remained in the Works and had come out top in the practical training school. It was rather surprising to people to see which side the boys chosen for executive positions came from, and he could say that the majority came from the practical side, in fact a 95% majority.

Mr. Forge replying said that he quite agreed regarding Company Law and Award 728 should be at every executive's finger tips. It could, of course, easily be included in the Works Administration Course. He was very pleased to hear that the result of the practical classes was so satisfactory. He had long had a strong feeling with regard to them. The only thing was that not every company to-day was willing to spare their boys and give the necessary time for it, but it did assist if one could arrange works practical classes, as they were given in the right atmosphere.

Mr. Thomson said that he would like to ask the lecturer whether he considered it necessary for a man applying for an Associate Membership of one of the Institutions to have to get a number of people in the Institutions to propose and second him after he had already passed the examination. It seemed to him that a man who was not specially connected with some firm, or had an interest in a firm, did not have any chance of becoming a Member of an Institution as it would be years before he could get the right number of people to propose and second his application.

Mr. Forge said that he quite agreed. He thought in some cases it was probably done in order to have some sort of check on what the applicant put down on his application form. He was always asked to give details of his apprenticeship. There was no great difficulty in getting a proposer and a seconder as usually the head of the depart-

ment was a member or the next in command, but when three others were required as well it was rather annoying.

PROFESSOR CAVE-BROWN-CAVE said that having served on qualification committees, he could assure them that it was really very necessary to have direct confidential information as to the correctness of applicants' claims and the extent of their practical qualification. A statement by a member that he had satisfied himself that a claim was true although he had not first-hand knowledge was sometimes accepted.

After all, a student working in a district in which there was a local branch could easily get to know the secretary or members sufficiently well to get their support if he was at all interested in the society.

The lecturer had referred to the desirability of having some scheme almost parallel to the National Certificate scheme to testify to the standard of an apprentice's practical experience. In the Coventry and Birmingham districts the employers had formed themselves into a Federation which issued Certificates to apprentices who had undergone satisfactory practical training. The way in which that satisfactory practical training was assessed was very carefully worked out, and certificates were issued under the joint arms of Coventry and Birmingham. It was a very much more imposing document than the corresponding Higher National Certificate. He thought the scheme was excellent.

MR. FORGE said that he thought it was an excellent idea and that a federation such as the one mentioned was very desirable.

PROFESSOR CAVE-BROWN-CAVE said that it was really giving practical effect to the suggestion made, and he thought everyone would agree that it was the employers or practical men in a large town who ought to decide at any rate which practical subjects a youngster should take. He assured them that from the academic point of view the very greatest importance would be attached to any conclusion arrived at under those circumstances which would indicate what experience showed to be really necessary.

MR. GAUNT said that reference had been made to the excellent scheme run by large firms such as Metropolitan Vickers, but he could not see how the small firms could achieve the same degree of success in their training. It seemed to him that the discussion had not quite answered that problem. It was vitally important that the apprentice supervisor should be a man of first-class qualifications. A small firm could not afford to pay the salary which such qualification demanded, and he would like to know whether it was possible for the University College or other educational institutions to provide such lecturers with up-to-date practical experience. It was a problem to which he could not see the answer except that it

meant that there would have to be higher salaries offered in the teaching profession.

MR. FORGE said that if those subjects were to come to the Universities he thought it was essential that the Universities should have the pick of the best men they could find to teach them.

PROFESSOR CAVE-BROWN-CAVE said that he thought a great many of the subjects should not come to the Universities. After all, they did organise a certain number of classes, mostly of the practical type, for the instructors were the very men under whom the apprentices worked at their firm. The college provided the accommodation and arranged the examination and the certificate.

MR. GAUNT agreed that that was how it should be done, but, with the small firms, could you afford a man of the necessary calibre to deal with that side of the training ? Should not there be some pooling of resources to achieve that ?

PROFESSOR CAVE said that he thought the best way of dealing with practical subjects was that the bigger firms should agree to take apprentices from the smaller firms for the purpose of instruction, and he thought they would be perfectly justified in charging a moderate fee for teaching them. He honestly thought that this was the best way to do it because a small firm could not give an apprentice all the instruction which was necessary, although in some respects the apprentice in a small firm gained better experience than an apprentice in a larger firm.

MR. FORGE said that somebody had got to make a move if anything was to be done about an employers' conference. It would probably have to come from one of the institutions and he would very much like to see the Institution of Production Engineers "father" it.

PROFESSOR CAVE-BROWN-CAVE said that it was most unfortunately a characteristic of discussions of that nature that they came to no conclusion which was recorded. He would like to see definite conclusions reached, recorded and acted upon locally. He felt that if reported to headquarters they would recieve the strong encouragement of council and especially of Lord Nuffield, the President.

MR. FORGE said that he felt convinced that the Institution of Production Engineers was sufficiently well established in the south and sufficiently widely known for any communication emanating from the local president of that institution to be received with a certain amount of attention. Whether it would be better to bring it under the auspices of the institution or privately was a matter for discussion.

MR. DENNY said that he had listened to all the remarks with great interest, and he was sure that Mr. Forge and the committee would be only too pleased to attend to any suggestions that were put forward by any local firm and see how much could be done to "keep the ball rolling." He quite agreed with Professor Cave-

Brown-Cave when he said that it seemed such a pity that a subject like that should be suddenly dropped when they all left that room. It was a subject which was of very great importance to all the people connected with engineering, and in the industry to-day they were suffering because of the lack of training a few years ago. The difficulty of getting trained people, and particularly junior administrative staff, was holding back all the enormous programme which was trying to go forward, and if some intelligent form of apprentice training was really decided upon on a basis which would not be too difficult for even a small firm to handle, he was sure it would be of very great assistance to production engineering to-day.

So if any of them who represented firms would like to consider the subject with the idea of something being done he was sure the committee of the Southern Section would give it every sympathy and see how much they could do to help to keep it going.

PRESSURE DIE CASTING.

Paper presented to the Institution, London Section, by Hans Lawetzky, M.E.

PERMANENT moulds for the production of repetition castings have been in use for a considerable period, but the pressure die casting process is a comparatively new development, and where quantities of accurate castings are required, the pressure die-casting method is the most economical so far known to science. In the present state of development, regarding the high compression of the metals cast, it can be placed as an intermediate process between casting and hot stamping.

Various attempts have been made from time to time to improve casting procedures using permanent moulds and the gravity die-casting process. The main difficulties encountered in the latter consist in premature chilling of the cast metal, and, further, the incomplete filling of the dies. Sharp edges and thin wall sizes can seldom be attained.

To overcome these difficulties, pressure was applied to the metal, to force it into the die. The first machines built to work according to this principle employed a pressure chamber submerged into the pot of liquid metal and had a piston fitted into this chamber to press the metal therefrom into the die. Certain types of these machines are still employed, but they can only be used for the casting of metals with a low melting point, as for instance lead, tin and zinc alloys. As later shall be explained, even for the casting of these latter alloys, the application of these machines is limited, due to insufficient injection pressure. Metals having a higher melting point, could not be worked with these machines, since the pressure chamber either would not withstand the heat or it would be impossible to maintain permanently a good fit between pressure chamber and injection piston.

A later development abandoned for this reason the plunger pressure and applied gas pressure upon the metal, contained in the pressure chamber to inject it into the die. With this method it was possible to cast aluminium alloys, but there were still a number of drawbacks, which limited the application of these machines.

For instance, the pressure chamber was still subjected to the heat of the molten metal and, since pressure was applied to it, excessive wear took place. The only material which could successfully be used for these pressure chambers was steel, and when casting

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aluminium alloys, the steel was dissolved by the liquid alnminium and, consequently, the mechanical properties of the aluminium alloys reduced by excessive iron-contents. Furthermore, the pressure was limited by the gas compressors which would not work economically at pressures above 700 lb. per square inch. Extensive tests proved that the pressures required for the formation of a fine grain casting exceed considerably these values. For these reasons it was necessary to return to the original type which applied piston pressure and to find ways and means of reducing the excessive wear of the piston and pressure chamber.

As before mentioned, the main reason for this rapid wear was due to the excessive heat to which the piston and pressure chamber were subjected. Therefore, the solution would be to isolate these parts from the continuous contact with the liquid metal: in the latest constructions of pressure casting machines the metal container is entirely separated from the pressure chamber. Metal is heated in a separate furnace placed near the pressure casting machine and transferred by means of a small ladle into the pressure chamber, wherefrom it is immediately, by the action of the plunger, pressed into the die cavity. The pressure chamber thus is only for a very short time in contact with the hot metal and remains comparatively cool. A correct definition for this late type of machine is "Hydraulic pressure die casting machines with cold pressure chamber" or shortly, as their manufacturers call them, "Pressure Casting Machines."

The principle of the cold pressure chamber is based on the following idea. Immediately, the molten metal enters the pressure chamber, it forms a thin skin or crust of solid metal all around which is chilled by the walls of the pressure chamber and by the access of air. This thin crust acts as a packing for the injection piston, which can therefore be given enough clearance to prevent excessive wear between the walls of the pressure chamber and the piston. The pressure chamber being relatively cold, the limit of compression is regulated only by the tensile strength of the steel used, and thus practically any pressure may be attained.

The results of tests, mentioned before, to ascertain the most suitable pressure, gave the following results: Zinc alloy, pressure-cast at a temperature of 430 centigrades and above, with a pressure on the metal of 5,000 lb. per square inch attains tensile strength up to 47.500 lb. per square inch and an elongation of up to 12% A special feature of casting these metals at high temperatures, which is only possible in pressure casting machines when the indicated pressure should be attained, is the exceedingly dense skin of the castings which is absolutely necessary for the galvanic plating to which most of the castings are subjected. Formerly it often was felt as a big drawback, that with castings produced by other

methods the plated surface was quickly destroyed due to intergranular corrosion, causing a galvanic destruction of the plating. These difficulties have been entirely overcome and zinc castings, used to-day, for instance in large quantitites in motor car manufacture, will keep their finish through years without any sign of wear.

It should be mentioned that high casting temperatures are not recommended for every metal cast, but are only a feature for the zinc alloys called Zamak or Mazak based upon a zinc having a purity of 99.99, and for several aluminium alloys, mentioned later in this paper. For a number of other alloys it is essential to reduce the casting temperature as far as possible and it is a big feature of the pressure casting machines, that as they do not depend upon the gravity flow of the metal into the pressure chamber, it is possible to work with semi-solid metal if necessary. Reference will be made to this when speaking about the copper base alloys.

For light metals having aluminium base, pressures varying between 2,800 and 4,900 lb. per square inch are the most favourable. For the casting temperature no definite indications can be given; for some alloys the temperature must not exceed 580°C., whereas other alloys which require to be heat treated, are cast at 70° to 780° C. Some of these latter alloys after heat treatment have a tensile strength of 26 tons per square inch, equal to that of a steel forging.

Formerly it was impossible to heat treat die castings, owing to the difficulty of producing die castings free from air inclusions. Air inclusions expand when the castings are heated and form bubbles or blisters on the surface of the casting. With a combination of the high injecting pressure together with high temperatures it is possible to produce castings that can be treated, thereby producing parts which are to be subjected to high stresses.

Magnesium alloys known commercially as dow-metal or electron are difficult metals to cast. As known, these alloys are highly inflammable and for many years there was only one special machine that would deal with these metals satisfactorily. This machine, working on the principle of the old zinc machines, kept the metal in an airtight container and was therefore very delicate to handle and was very complicated. Moreover for reasons before stated, the early machines dealing with zinc alloys could not be built to obtain sufficient high pressure upon the metal. Latest developments introduced a special furnace to charge the metal in portion as required for each shot into the machine while keeping the main portion of the metal in a closed vessel with a neutral atmosphere. There is no difficulty in keeping the vessel tight since it does not contain any moving parts. In combination with a furnace of this kind the pressure casting machines have proved their suitability and superiority for working these alloys. Casting at a temperature of 600° to

630° C. with a compression 5,600 lb. per square inch, a tensile strength of 14 tons has been attained.

The last group of metals which can be pressure cast economically are the copper base alloys. The difficulties in the working of these alloys is in obtaining and maintaining the durability of the dies. Due to the high melting point of the material, the strain on the die steel would be excessive if cast in liquid state. The solution of this problem therefore is to work these alloys at a temperature well below the melting point, at which temperature they are in a semi-liquid or plastic condition. Naturally the metal in such a state requires a very high compression and the reduction in temperature is compensated by increased plunger pressure. The pressure casting machines, therefore, are the only machines that will deal satisfactorily with copper base alloys.

The compression for copper base alloys should be at least 6,000 lb. per square inch, but pressures up to 8,500 lb. per square inch are commonly used. Even high values may be attained but their application in general is prohibited by the presence of cores which would suffer by the increased mechanical strain combined with the thermical erosion due to the metal temperature. The casting temperature for brass amounts to 850° to 900°C. according to composition. It is very important that the temperature is never raised above the evaporation temperature of zinc, since this eliminates gas inclusion in the castings. Other copper base alloys which may be die cast are special bronzes or brass with nickel, manganese and silicon contents which have high corrosion resistance and tensile strength, also German silver with a nickel content up to 9%. A higher percentage nickel in German silver is not recommended, since the casting temperature would be too high and thus quickly spoil the dies, making dubious the economy of the procedure.

The mechanical properties of copper base alloy pressure castings excel sometimes the corresponding figures for good structural steel. The tensile strength ammounts to 22 to 47 tons per square inch and the elongation to 6 to 14%.

Trials have been made to cast gunmetal, and although the results have been favourable, this work cannot be regarded as an economical proposition due to excessive wear of the dies.

In the United States of America and in Russia pressure die casting machines for grey iron casting have been developed. Both machines approach the problem from different angles, the Russian machine following similar lines to the hot stamping process, the American machine employing the principle of one of the early aluminium casting machines. In both cases much experimental work has still to be done and it is not yet a commercial possibility. The American machine will deal with at least 50 lb. of metal with each shot ; the

Russians, on the other hand, have not succeeded in producing castings weighing more than 1 to 2 ozs. These indications show clearly the present limitations of the process which are due very largely to the absence of suitable material for the dies. Only after a new and better die material has been found may we expect to proceed really with the practical development of cast iron die casting on a large scale.

I would now like to describe in detail a modern hydraulic pressure casting plant which embodies all the improvements and accessories which have been found necessary and which are the result of years of research and shop practice under various conditions. Such machines can be applied without any alterations for the manufacture of any casting and of any metal within the power limits of its design.

Hydraulic power supply has been selected after careful trials as being the most suitable for the job. It gives uniform pressure speed and power independent of the length of the stroke which is very important for the injection of the metal, as I shall point out later in detail.

Hydraulic pressure is also the most suitable means for the locking of the dies. The metal when filling the die exerts a large pressure, which tends to open the die. Due to the elasticity of the material from which the machine is built the elastic elongations would be sufficient to permit a slight opening of the die valves if a rigid mechanical device was applied to them. The hydraulic pressure, on the contrary, compensates for such elongation of the material and the hydraulic control moreover gives automatically an additional locking power exactly at the moment at which the forces tending to separate the dies attain their utmost limits.

The required pressure is supplied by a hydraulic pump of a suitable design, capable of giving the necessary pressures. The pump delivers the fluid into an airloaded accumulator, to which the pressure casting machine is connected.

The application of the air loaded type of accumulator in connection with pressure casting machines is very important. It combines the feature of the quick action of the air pressure with the rigidity of stroke which only hydraulic action can supply. Air pressure alone proved to be too elastic to produce the optimum results for the injection of the metal. Hydraulic pressure, on the other hand, supplied from the pump directly or from a weight loaded accumulator did not permit the developments of the high speed as often required for the casting.

The illustration shown in plate 1, Fig. 1 shows a machine of latest design, and Fig. 2 shows another Polak machine at work. The verticle ram in the front of the picture carries the injecting plunger which applies pressure to the metal poured into the compression

chamber, the opening of which is to be seen underneath the plunger. The stationary half of the die is fixed to the back side of the vertical press and with a sprue nozz'e connected to the compression chamber. The large square plate at the back represents the die-character, to which the moving half of the die is connected. In the back position, the die is open and the castings are ejected. To close the die, the die-carrier is forced forward by a horizontal hydraulic ram until the moving die-half is tightly pressed against the stationary one. In this position metal is poured into the compression chamber and immediately after the injecting plunger descends to squeeze the metal into the die.

It would be difficult to measure always exactly the quantity required for each casting and, moreover, there would be no possibility of exercising an extended compression, as is often desirable for heavy castings. The amount of metal to each charge is measured approximately by the size of the ladle employed, which is slightly more than is actually required to fill the die. A residue remains at the end of the injecting operation in the compression chamber. This is ejected on the return stroke of the plunger. The die is then opened and the casting ejected.

The control of all the machine movements is effectuated by foot pedals. To ensure maximum production the distributor is so constructed that these foot pedals are operated without exertion to prevent fatigue to the operator.

It is essential for the casting of different alloys to be able to regulate the injecting pressures. Since it is difficult to change the hydraulic pressure of an entire plant, a device is attached to the machine to regulate the pressure on the injecting plunger while retaining constant pressure on the accumulator. The two spindle heads shown in the middle of the vertical cylinder serve for this purpose. These spindles open and close two valves and according to their relative opening the pressure can be reduced from its maximum value down to one fifth of same.

Another condition which has to be fulfilled is the regulation of the speed of injection, since nearly every casting requires different speeds and pressures according to shape and gating. The throttle screw at the side of the main distributor controls the passage of the water to the injecting cylinder and permits exact setting of the speed within widest limits.

The machine as illustrated is one of the largest of its kind, if not the largest in the world. It is capable of casting aluminium alloys up to a weight of 18 lb., or brass parts up to 40 lb., which calls for a very powerful machine, Nevertheless, the power consumption is relatively very small, since the construction incorporates a pressure saving device, which enables the machine to perform the operation

with a minimum amount of power and applies the full pressure only for the short time it is actually required. The large tank at the back of the machine and the automatic valve shown at the extreme left in the back, form part of this device. Fig. 3 shows another design of Polak machine and Fig. 4 illustrates casting die with hydraulic core extractors in operation. Other casting dies are shown in Figs. 5 and 6.

Most of the die castings to be manufactured have cores, in which case it necessary to provide means for extracting same when constructing the dies. A modern die-casting machine has to incorporate the equipment for the core extraction. Thus it is possible to reduce thedie cost, ssincestandardised core pulling units are easilyconnected to the die blocks. In a hydraulic machine, as illustrated it is evidently the most appropriate way to provide such core pulling equipment of hydraulic construction.

The distributor block at the top of the die carrier has an adequate number of connecting nipples to connect any amount of such core pulling units as may be desired for any die. In most cases the extraction of the cores should be effectuated after separating the die halves during the opening movement of the die. For this purpose an automatic control is provided for controlling the cores independant of the die carrier movement. Sometimes it is advisable to actuate the core extraction while the die is still closed or to withdraw one core sooner than the others. A hand operated control is then provided, to be actuated as desired.

Concerning the construction of the dies, no definite rules whatsoever can be established. The design of the die in a large measure depends upon the kind of machine employed and the number of castings to be produced. The dies consist in every case of the actual die blocks containing the cavities, and of the cores and ejectors with the necessary devices for their movements. Fixtures have to be provided to fit the dies to the machines, and to connect the core extracting and ejecting devices to the die blocks.

As a rule, material used for the die block for commercial pressure die casting is steel. The higher the melting point of the alloy to be cast and the larger the quantity of castings which have to be produced, the better is the quality of steel used for the dies.

For small quantities of zinc alloy castings, low carbon content steel may be recommended ; for quantities above 50,000 castings nickel chromium steel should be used. Aluminium castings require die steels of the chrome vanadium or of the high chromium content type. These latter are also employed for the manufacture of small quantities of copper alloy castings, the best steel brands for large quantities of brass castings are the chromium steels, to which sometimes cobalt is added.

In general practice dies are hardened, since they resist better the mechanical wear ; the hardening also prevents the sticking of the metal to the die. This is especially important for the casting of aluminium alloys which require a die hardness of at least 46-52 Rockwell C scale. To prevent tempering of the dies owing to the heat of the metal and to accelerate the solidification of the castings, all the dies are water cooled. Precautions are taken to prevent too intensive change between the cooled portion and the die cavity itself. For this purpose, copper pipes are inserted into the cooling channels or the cooling channels are often provided in a separate plate, which is fitted to the back of the die blocks.

Gating and venting, apart from being different for each type of machine, depend also on the shape of the casting and of the alloy used. The design and dimensions of these components is a matter of experience and varies with every casting process. The section of the gate at its smallest part is very important and, although it naturally depends on the size of the castings, the depth of this section in general remains in certain limits for every alloy, and only the width varies according to the weight of the castings. The limits for the depth of zinc castings are between 0.003 and 0.016 in., for aluminium castings and light metal castings in general between 0.06 and 0.15, and for copper alloy castings between 0.06 and 0.12. Venting very often is not necessary, since there is always a certain space between the die surfaces and between die and cores. For very intricate castings and for such details where even very small blow holes must be prevented, shallow gaps are ground into the die on the parting line permitting the air to escape, whereas, due to their shallowness, metal will not enter. Experiments have been made with a view to evacuating the air from the die cavity, but the results have not been satisfactory and have been abandoned except in lead alloys, and one automatic machine for casting tin and except for a special method of casting aluminium bronze, which has no actual connection with the subject of this paper.

As most jobs to be produced are cored, the designer has to observe certain rules in anticipation that the piece may later be produced by pressure die-casting. Collapsible cores, in spite of the many different methods which have been tried out, have not been very successful. The designer should take great care to omit undercuts in the castings or cores, which would make it impossible to withdraw the core or the casting from the die.

In some cases it is possible to design the dies so that the cores may be also stationary in the die and the casting stripped from the core. In any case only the relative movement between casting and core is of importance. Sometimes, also, bent cores may be employed, as for instance in the production of water taps. The bend must in these circumstances form part of circle to be withdrawn in the

prolongation of the same. There are a number of devices for the extracting of the core which have to work as quickly and safely as possible so as not to influence the production rate of the machine. The number of castings to be produced usually determines what kind of devices are to be employed.

Where the number of castings required is small, the simplest devices are employed to reduce the die costs, even at the cost of a slight decrease in the production rate, since it would be impossible to amortise high die costs on the smaller output. Standardised core extracting and ejecting devices are a big help in production, but their application depends on the kind of machine used, since only very few machines are suitably equipped.

The most simple and common construction of such devices is of the mechanical type, the cores being moved by rack and pinion. The pinion then is turned either by hand, by means of a lever, or alternatively, automatically through the medium of cams and connecting rods. Sometimes the cores are directly in connection with a cam which withdraws them from the casting during the return stroke of the movable die. Hydraulically or pneumatically operated machines permit the extraction of the cores by means of small cylinders, controlled by the main pressure fluid. These cylinders enable the extraction of the cores at the desired time, independent of the movement of the die and it is only a matter of taste whether to control them by hand or automatically. A further advantage of the core extracting units is the fact that these can be standardised and employed for various dies, thereby reducing the cost of the die considerably.

For the ejecting devices, the same rules are applied as for the core extraction, but it should be pointed out that for very complicated castings it is often preferable to actuate the ejecting device by hand even when the construction may permit an automatic ejector, due to the fact that the hand operation keeps the operator in touch with the work. He at once feels any little thing which goes wrong, as, for instance, insufficient cooling, or other little defect in the functioning of the die. It enables him to locate the trouble before any serious damage is done.

The art of die-casting is still in its infancy. Every day new fields for its application are discovered, and it is difficult to forecast how far reaching the ultimate results will be. One of the governing factors of to-day's limits is the question of suitable die material. Until this is considerably improved, it is only possible—always allowing for a small number of exceptions—to employ pressure die casting methods to materials with a melting point below 1,000° to 1050°C. Below this melting point any metal and alloy can be pressure cast which can be cast or forged. The economic limit depends on the individual instances. Sometimes for large and

complicated parts an order of several hundred pieces warrants the cost of the dies ; as a general rule any order above 5,000 pieces executed by pressure casting will be produced cheaper than by any other method.

With regard to the size and weight of the castings, no limits are to be established for the minimum size that can be produced. It is possible to produce die castings weighing a part of an ounce and measuring a fraction of an inch. On the large side, the limits are determined by the machine employed. The largest machines will produce castings up to a size of radiator grills and up to weight of 50 lb., but there is no reason whatsoever why these limits should not be surpassed and larger machines built meeting the requirements of some industry which has not yet considered the use of this comparatively new method. A machine is now under construction which will produce castings in aluminium alloys up to a weight of 35 lb., which in size equals a zinc casting weighing 100 lb., with an area of 5 sq. ft. This machine is destined for the motor car trade, and for the armament industry who have, especially in the last two years, been large buyers of pressure die castings.

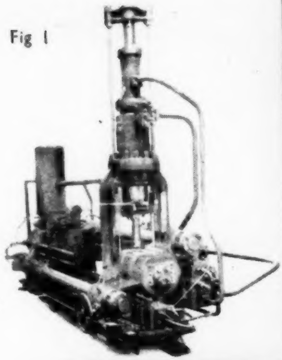
The material to be die cast sets the limits to the precision of the castings. The lower the casting temperature of the metal the higher is the precision.

The first condition to attain a close accuracy of the casting consists in precision manufacture of the die. Granted this, it is possible to observe a precision of plus minus 0.15% at least .001 in. In the manufacture of zinc and aluminium alloy castings, a tolerance of plus or minus 0.2% and 0.002 when producing aluminium alloy castings, and, finally, of plus or minus 0.25% and at least .004 for the manufacture of pressure castings having a copper base alloy. The limits indicated here demonstrate the absolute minimum values and rise already when inserts to the die are used. Allowances have to be made for slight displacement of the latter on account of dirt or metal traces. Comparing these figures and tolerances with the allowances permitted in the manufacture of most articles, it will be seen that very often all machining costs can be saved and in fact it is often possible to assemble die castings straight as they come from the machine.

As before stated, pressure die casting is still in its early stages ; the application of it grows continually. The examples I shall show you here are therefore really only a few of what are being and can be done.

To-day's most important customers for die castings are the motor car manufacturers and the motor accessory manufacturers in general, household and office equipment, machinery manufacturers, suppliers of electric equipment, makers of precision and optical instruments, radio and telephone factories, movie and photo-

Fig 1



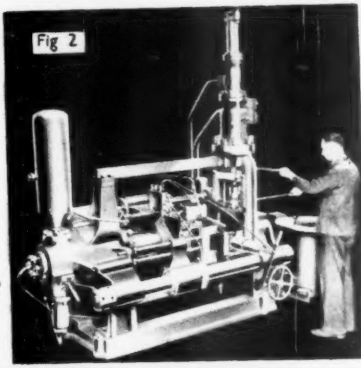


Fig 2

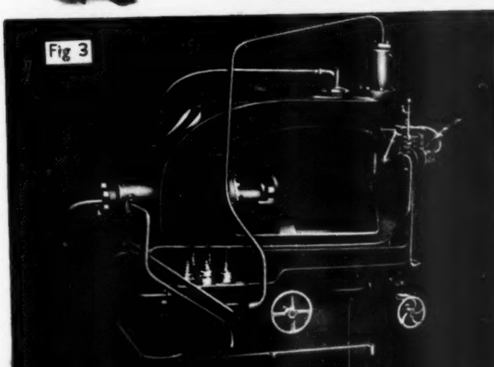


Fig 3

Fig 4

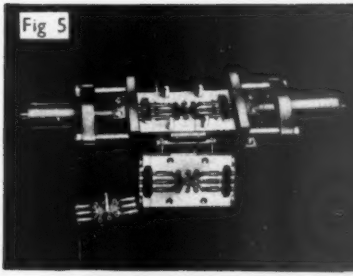


Fig 5

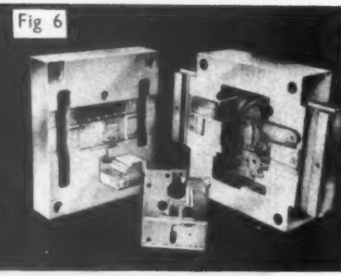


Fig 6

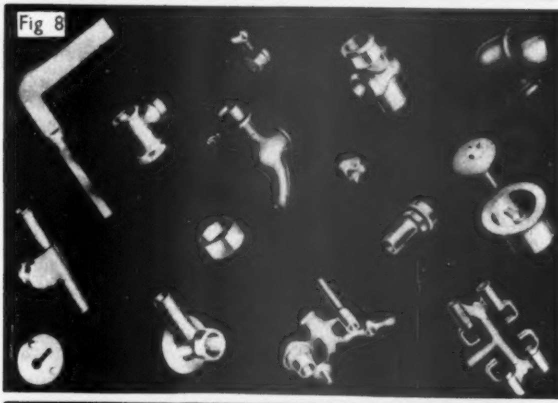


Fig 8

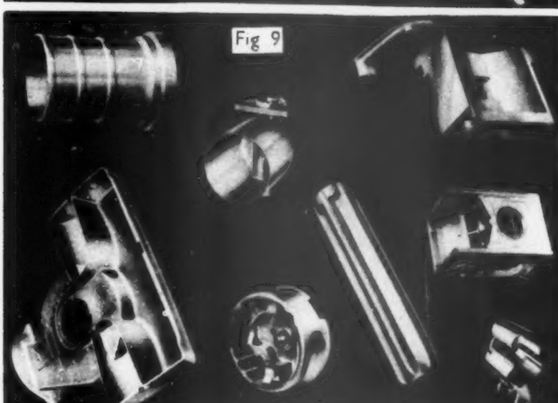


Fig 9

Fig 7

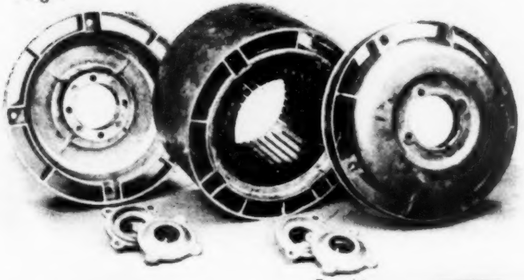
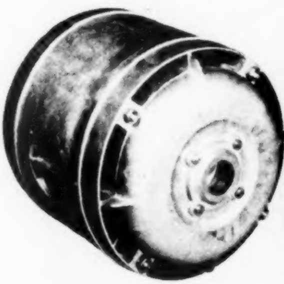


Fig 11



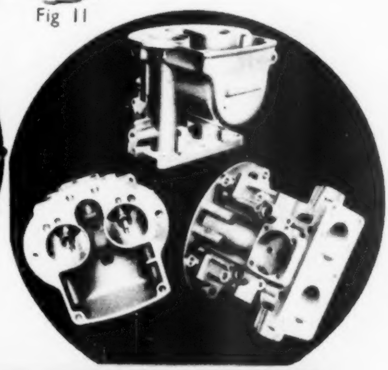


Fig 10


Fig 12

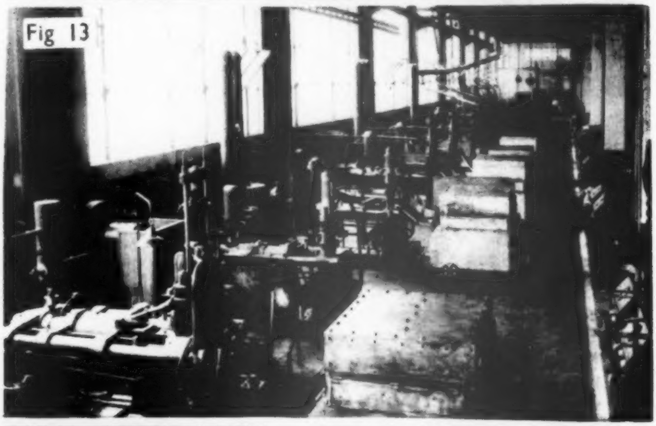


Fig 13

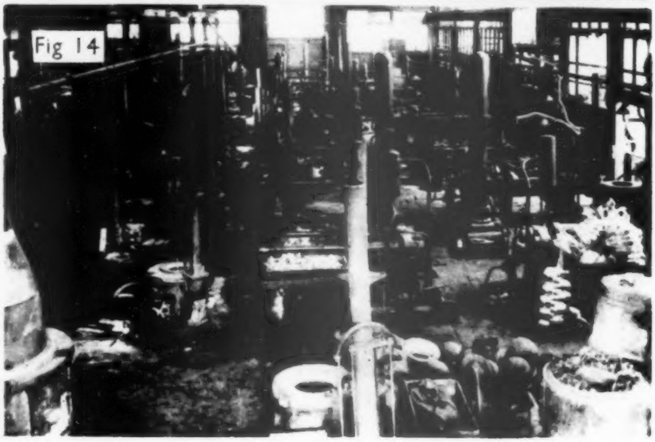


Fig 14

camera producers, low priced stores with all kinds of small metal goods, maufacturers of slot machines, and finally, especially for the copper alloy castings, plumbers' and builders' hardware manufacturers.

The pictures of different die castings illustrated in Plates 2 and 3 show you better than words could express how different the shape and application of such castings may be.

Concerning the amount of pressure die castings produced, the United States of America not only are the pioneers of the die casting industry, but they are also the largest manufacturers and users due to their large home market, which calls for very large quantities.

Take, for instance, motor car manufacture with its 1936 output of nearly 5,000,000 cars. As previously mentioned, fittings, carburettors, windshield wipers, pistons, electrical equipment, radiator grills, or louvres, sometimes even parts of the motor block are pressure die cast. Allowing the low average of say 9 lb. of pressure die castings per car, this industry alone would absorb 20,000 tons of castings per year.

In 1932 an American firm imported from Europe the first pressure casting machine for making brass castings. Up-to-date, this firm alone has produced more than 10,000,000 castings with these machines, supplying them to the hardware trade, for butchers' equipment for electrical accessories or even for cutlery. The manufacture of zinc pressure castings in the United States during 1936, roughly estimated, would amount to approximately 60,000 tons, that of light metal castings, to 12,000 tons, and of copper alloy castings several thousands of tons.

The main difference between the handling of the pressure die casting business in the United States and in Europe consists in the fact that in the U.S. it is almost exclusively handled by big concerns taking on jobbing work to anybody's order, whereas in Europe a large number of smaller factories produce for their own requirements only. There naturally are European factories which accept orders for pressure die castings too, but these are exceptions and the general trend is for each firm to install a pressure die casting department to cover it's own requirements. In Europe the largest consumer and producer of die castings is Germany, especially due to the four year's plan. The pressure casting of zinc and aluminium alloys has made rapid progress, since these metals are " German materials," found and refined entirely within German territory.

It is very difficult to estimate the total production of die castings in European countries to-day, since no figures are published; but based upon the estimate of 1928, and according to my own experience, in Germany, for instance, the production of pressure die castings must have increased at least tenfold in the last few

years, and can be roughly estimated to-day to be about 30,000 to 40,000 tons per year, 2,000 tons of which are castings of copper alloys, thus exceeding with the last item the production of the United States.

In England the development during the last five years has been very rapid, but industries in general do not yet fully appreciate the advantages of this process. There are, however, two factories in England which have no equal in size and equipment in any other European country. The production of these two plants alone amounts to approximately 5,000 to 6,000 tons of castings per year. It would be safe to assume that the entire production of the British Isles would be about two to three times this figure, amounting to some 20,000 tons per annum.

A considerable number of very modern plants have been installed in Russia, but their production is still very low. Other countries on the continent have been making good progress with the process. France, Italy, Czechoslovakia, Switzerland, Sweden, Holland, Belgium, Poland, and Hungary are utilising the process successfully. Even countries such as Finland, Estonia, Bulgaria, Greece, and Turkey, which cannot be classed as manufacturing countries, have put up installations for the manufacture mainly of hardware goods, made from copper base alloys with the pressure casting machines.

In the Far East Japan is leading with a production about equal to that of England. Other countries overseas have also adopted the pressure die casting process. China, Australia, India, Egypt, South Africa, and South America utilise the process for special requirements.

Finally in Plates 4, Figs. 12 to 14, I show you a few plants which should give an idea of the appearance of a modern die casting installation.

Discussion.

MR. MUNDY: It has given me a very great deal of pleasure to come to hear this lecture. I had the pleasure of coming and holding forth on die castings some ten or twelve years ago to this Institution, and die castings then had not reached anything like the point which they have now. It was pointed out to me before we started that a lot of metal had passed through the dies since I spoke to this Institution. I would really like to congratulate our lecturer on his immense and deep knowledge of the machines that are on the market, his deep knowledge of the parts that can be made by die casting processes, and his wonderful mastery of the language which we use and to which he is more or less unfamiliar.

The company with which I have been associated over a good many years were doing die casting just about seventeen or eighteen years ago, and we bought a very little machine to make a very small die casting. I had seen die castings quite ten years before that. They were small speedometer parts; but die casting had a dreadful setback some time after that, because the makers of die castings wanted to be too cheap and were in too much of a hurry, and they did not get the co-operation of the right men. They did not get foundrymen, they got engineers. Engineers did not know much about foundry work, and shame to say, they knew less about casting, and so it came about that it was the designer who actually was able to put die casting on its feet.

The chief under whom I have served for a good many years was a wise man, and he set to work to get a team of people round him who would combine the engineer and the designer, and if we have had any success I am sure it is owing to the marvellous design of dies by a team of designers under Mr. Pechal, and may I say the die makers themselves who are not mechanics but artists, and also the metallurgist who found the right metal.

Some ten years ago, my fellow directors decided to send me to Prague to see Mr. Josef Polák, and we are extraordinary fortunate to have a relation of Mr. Polák here this evening describing these die casting machines I had Mr. Pechal with me who not only knew the language, but knew all about die castings that was known then. We saw Mr. Josef Polák's first real effort at pressure die casting. It was a very elementary machine as compared with those machines which we have seen illustrated this evening, but it was a wonderful machine and had all the pieces which have been pointed out to us.

I have always been something of a psychologist with regard to workmen, and in watching our die casting workmen operating a

hand operated machine by means of a long lever, I noticed that they did not always pull with the same kind of pull. Sometimes they gave a sharp pull and sometimes they gave a good follow-through when they wanted a good pull. They sometimes pull with a sharp pull and sometimes with a long follow-through. Now Mr. Polák with his great ingenuity succeeded in copying that, and you cannot do it by a mere hydraulic machine. Reason how you will, we cannot get away from the law of hydrostatics that fluids under pressure exert equal pressure in all directions, but he introduced the air cylinder, which not only gave speed but which gave that resilience and elasticity to the thrust which gave the follow-through, which is very largely the reason for the success of these machines which have been shown us to-night. It is that pneumatic power—in point of fact the machines are hydro-pneumatic and not merely hydraulic —and they are better even than our lecturer has said.

We have not said very much about metals this evening. The engineers do not think much of metals. I do not care what kind of machine you use, you want the metal in every job. You have seen the large number of articles that can be made, but they want the right stuff in them. I stopped to mention a moment or two ago that die castings had a dreadful setback. That setback was because they did not study metallurgy. Metals were chosen which would make a successful casting, that is to say, which would fill the mould and would come out of it, but they did not consider the fact that certain alloys have a very nasty habit of growing, storage hardening and storage cracking, not merely due to differences in section thickness and thinness, but due to some crystallized growth. So much work has been done now on the internal structure of the alloys that we do know that certain alloys have a tendency to grow, and that growth causes small cracks, that storage change of form however slight causes wall cracks, and zinc alloys—zinc base alloys which are cracked ever so little emit moisture and air, and moisture causes internal corrosion. The stresses which are internal become stronger and the parts soon become completely spoilt. I know one particular firm who turned down die castings. It cost them £20,000 in one go over one job which they did, and it was a long time before anyone dared to mention die castings to any of the responsible engineers in that company. But that has now, I am glad to say, been largely overcome.

Our lecturer has mentioned something about the alloys and zinc base alloys which seem to be most important as so much more of this alloy is used than anything else. The zinc must be very pure, and the aluminium and copper must also be as pure as can be obtained, but the zinc must be particularly pure or you will have storage crackings and bad castings.

I believe that the greatest die casting, the greatest die caster, in the world is a printer's. Every bit of type that is made is a die casting, and a very beautiful die casting too.

The lecturer gave a description of how, when the metal was poured into the container, a sort of egg-shell casting was first of all formed. That was not and has not been my constant observation. It is very largely in my view due first of all to the fact that it does not run down owing to difference in surface tension. Secondly, there is in all metals which are best die cast, particularly the copper base metals, a considerable period of plasticity due to the different smelting points of these alloys. That is to say, that the alloys have not a single melting and a single solidifying point, but they solidify over a range of temperatures, and it is during that period of plasticity when the metal is in a slightly plastic condition, when some crystals of a higher melting point constituent have been included, that the metal can be moulded, It is actually being moulded like putty, or, better still, like the snowball is moulded and squeezed together. That is the main feature of the high value of these die casting processes, that the pressure goes on and is exerted continuously until the metal has solidified. I hope that is clear. It is not merely, I think, a case of chiefly taking advantage of the fact that the metal just hardens round the edge, round the outside, but it is also due to this factor. It is taking advantage of this purely physical fact that the majority of alloys which are used have a range of plasticity, or what the metallurgist terms a solidus and a liquidus. The best illustration I can possibly give you just to bring to your mind is the making of a plumber's joint. The old-fashioned plumber always used to favour metal, nowadays plumber's solder, which he put into a piece of leather and then just at the right time he generally put a piece of paper to see that it had reached the right temperature, and then he moulded the wide joint round the two ends of the pipe. Nowadays I fancy they mostly mould it by a blow lamp. It is partly solid and partly liquid and there is a very long range of temperature in a plumber's solvent, between 70° and 80° C. of the first solidification and the final solidification, so there is plenty of time to do it in. This also obtains very largely in the copper alloys.

Mr. Lawetzky : There is a difference between the different metals. Zinc metals, according to my experience, are cast in a liquid state, the higher the temperature the better, and for this alloy and for certain aluminium alloys this is the case, as I told you in the beginning, that this metal forms, when it has been poured into the pressure container, a crust—it is, let us say, like an orange in the container, and when it is squeezed out the juice is forced through the shell. For the copper alloys as I have told you it is better to cast them in the plastic state, as Mr. Mundy has mentioned

and I am very thankful to him for having pointed this out since I did not lay enough weight on it.

Concerning metals, I have told you something about the zinc metals used, a little about copper alloys used, and not much about aluminium. To speak about the alloys used to-day in die casting would mean about two days of continuous talking. I have checked up alone a few books from metallurgists about tin, lead, and zinc alloys. I believe I have found in four books not less than 200 to 210 different alloys. You will agree with me that it would take quite a time to speak about all those alloys. I have some very good metallurgy books where you can look into this matter and, as Mr. Mundy has pointed out, and I have told you, it is generally very important for die casting to have as clean a base metal as possible. Zinc Metals have been specially developed very recently, and a new process has been found for refining aluminium up to a purity of 99.97, which is of special importance for the manufacture of those motors I have been speaking about, but this metal must have a high conductivity in order to give you the very best efficiency for electricity.

Concerning the copper alloys, those mostly used are brass. The silicon compound I was speaking about is another excellent alloy which gives very good results. There are also manganese bronzes, or, to speak correctly, brasses with manganese content, but with regard to other alloys such as gunmetal and German silver, I have told you to what extent they might be used.

Concerning the air loaded accumulator, the combination of air and hydraulic pressure, I had this in my paper to-night but unfortunately I forgot about it. In going through my notes I must have turned over two pages instead of one.

MR. WHITE: I was very interested in looking at the various machines which were illustrated, and I noticed that actually only one machine as far as I could see was a self-contained unit, and I rather gather that most of the firms are presumably using the accumulator system, supplying the pressure from some central source. I should be interested to know what the lecturer thinks of the independent machine as against an accumulator system. With regard to the goose neck machines, I should be interested to know the production figures you can get out of a machine of that type. Assuming you have three cores hydraulically operated, approximately what production would you estimate you would get out of the machine? When you put in a new die in a machine of that type, presumably there is a breaking-in period, could you advocate any forms of die dressing on new dies, or are there any special new dressings which you would advocate?

MR. LAWETZKY: With regard to the latter question, die dressing for breaking-in is especially important for the manufacture of

aluminium castings. For those castings there have been made special die dressings by every firm I have seen. All of them have the trend to build up graphite, either to apply directly, or to build it up by carbonization of the compound which they use. The best mixtures I have encountered are colloidal graphite, graphite in a solution of oil, and to some degree vegetable greases like cocoa butter. For zinc there is no special die dressing during the breaking-in period. Cores have to be lubricated to a certain extent all the time, whether in breaking-in or whether in full production, but not to a great extent. For brass if the die is properly hardened there need just be die dressing in the form of hardening, rehardening of the die surface, and for this I would suggest say a solution of potassium ferricalcite which spread into the die gives at least a very slight carbonisation of the surface and maybe a little nitratisation too. It is a matter of taste, to use these die dressings. Some of them have advantages for certain alloys and quite a good number of firms regard these dressings as their special secret. Those I have told you now are generally employed with only slight changes, which, according to my observations, do not give very many different results.

With regard to the question of output of such a machine with three cores, it naturally depends also on the configuration of castings you have and on their size, if hydraulic core extraction is used. You might in small parts come up to 1,800 shots within eight hours. I am speaking about record figures. The average you might obtain with a good run will be some 1,200 to 1,500. For the manufacture of bigger castings of the same complication the production comes down, and most complicated castings of very large size will not be manufactured to a greater extent than say about 350, sometimes even only 300 in eight hours. But this nevertheless is very satisfactory since in many cases they will not have other possibilities of manufacturing the detail in one piece at all but will have to manufacture in several pieces with other methods.

Mr. White: With regard to iron contamination, you recommend that the goose-neck type of machine be modified to have a relatively cool metal charge, operated by piston, and that this method of charging tends to obviate iron contamination. I should like to know of any scheme whereby one can metallise pots. I recently heard of a proposition for metallising the pots to prevent contamination of the aluminium. It has already been done, I believe, on such items as ladles, etc., and I should be glad to know whether it is possible to apply this process to the iron pot of the machine.

Mr. Lawetzky: I have not had much to do with those goose-neck types of machine. This question has not arisen with me, and I am afraid I cannot tell you anything about it.

MR. ROBERTSON : I think the lecturer remarked in the opening part of his talk this evening that the heat treatment of aluminium alloy castings had only been developed during the early part of this year. I have a distinct recollection that some six or seven years ago of a firm in Switzerland and one in this country very successfully heat treated aluminium castings. I should like to know whether this is correct ?

MR. LAWETZKY : The firm in Switzerland is known to me. I have been in very close touch with them on the question of heat treatment on aluminium alloys and they did not tell me anything. With regard to the firm in this country, I can only tell you from my experience. One of your leading concerns of high quality metals have been in touch with us during the last year and they have made tests for heat treatment and they were not successful, and they told us they have not succeeded in getting a die casting heat treated and would not be satisfied before it could be done. They have made many tests without success.

A VISITOR : I think there was a certain measure of success obtained by Dr. Rosenstein at the National Physical Laboratory on Alloys, but they were gravity die castings, not pressure die castings. They were cast in a solid mould. I saw it done myself. I agree with Mr. Lawetzky that we have made many tests with the aluminium alloys and without success.

MR. ROBERTSON : It was gravity castings to which I referred.

MR. LAWETZKY : Gravity castings have been done.

A VISITOR : I am interested in die castings with magnesium alloys and should like to know whether it is possible to pressure die cast magnesium alloys with a percentage of magnesium of 97%, and if so whether you would use chrome-vanadium steel for dies and a gate of .015 in. width, and what the ratio would be between the weight of the pressure cast article as against the gravity cast article.

MR. LAWETZKY : Magnesium alloy as you call it—it is called in Germany electron—is used very extensively in Germany on the electron machines, and with pressure casting machines with very good results. The gate of .015—I am sorry I shall have to convert in into millimetres—for the gate I should, according to my experience, advise you to enlarge it to a high extent for aluminium you might for a casting of medium size go up to five times that size ; for electron I should say two to three times this size would be sufficient. For the ratio, comparing pressure casting with gravity casting, in electron, you might reduce the size of the walls to less than .05 in. and in gravity die casting I believe the limits to be about $^1/_{10}$ in. or a little less, but not much less. So if you are able to reduce the wall size you might have a saving in weight up to 40%.

A Visitor: Just one further point. Would the pressure be somewhere about 5,000 lb. per square inch.

Mr. Lawetzky: Yes, very near to it.

A Visitor: I believe it was on a bronze casting that the sprue was connected to a ring on the end of the joint. What preference has that to the casting than screwing direct on to the job?

Mr. Lawetzky: The preference is that you have an all-round supply to the casting. You are not limited to a small gate to get the metal from the neck over the entire cylinder. You certainly will have made the experience in sand casting as in a good many cases in the manufacture of cylindrical parts this kind of gate is to be observed.

A Visitor: That would be all right if it were a complete cylinder, but supposing it was a return joint at 90°? Would not the sprue on the one cylinder be an advantage to the second cylinder at 90°? If you sprued direct into the cylinder you would have the 90°.

Mr. Lawetzky: I understand. I have made trials with both gates and in general found, nevertheless, that with this 90° angle the results to be better with the neck gate than with the straightforward one.

A Visitor: I take it that from the design point of view as regards deciding where a sprue on a casting would be, the best method would be to arrange to place the sprue so as to force the metal through the die with the least turbulence possible?

Mr. Lawetzky: Yes, that is right. It is sometimes shown to be preferable to take only one gate instead of two, since two gates give so much turbulence. There is just one point at which you may not get a metal at all.

A Visitor: Another point—is it preferable to sprue on a thin section in preference to a thick section? For instance, if you take a cylindrical box, I have known dies to be split at the bottom, meaning the bottom of the box, and sprued on the thick section, whereas other people have made the joint at the bottom of the box where you have got the thin section. Which has the greatest advantage? Would it be the thin section or the thick?

Mr. Lawetzky: Well, of course, that depends on the shape of the casting.

A Visitor: Taking a pure cylindrical box.

Mr. Lawetzky: You mean, for a cylindrical box with a bottom to it, would it be better to place the sprue at the bottom or on the top of it? Where is the thick section supposed to be?

A Visitor: At the bottom of the box, where you have got the thick section, whereas at the cylinder portion of the container you would have the thin section. Would it be preferable to sprue into the thick section or the thin?

MR. LAWETZKY: With a round box to cast with a thin section you are going from the walls into the bottom, and in general it might be said that the metal goes directly from the thin section into the thick one. It is better to place the sprue in the thin section, since it does not fill up first the thin and then the thick, but it spreads right into the thick and then up to the thin.

A VISITOR: Is it not a point that if you sprue into a thick section you get a certain amount of backward pressure? When the metal goes in you get the reaction going backwards on to the sprue and giving a bad section?

MR. LAWETZKY: When you cast in a thick section you will get the thin section filled up and then the metal might be too cold to fill the thick section entirely, and in this case you find the blow holes right behind the gate or behind the sprue in the thick section. There are exceptions naturally, but as the general rule I have found that these observations apply.

A VISITOR: If on trying out a die, supposing one limited the gate to say .015 and one found trouble with excessive blow holes, would that indicate that the sprue would have to be increased in size to overcome that?

MR. LAWETZKY: It depends. Generally I should advise increasing the size of the sprue, but it has to be considered whether it is a question of insufficient filling of the die, or to insufficient venting, because there is a big difference of blow holes on account of insufficient pressure and insufficient air escape. The included air is forced, and that might be prevented by venting properly.

MR. B. H. DYSON: I have certainly appreciated the "pressure" that our lecturer has put on this subject of die casting. I was rather hoping, however, that he would get down under the "metal folds" and into the "blow holes." I am afraid that when I see our weekly report of rejected die castings the word "die" appears more prominent than the casting part of it.

Has the length of the sprue, from the goose neck nozzle to the casting cavity in the die, any effect on casting? Also with regard to the sprue, should the cross sectional area at the entry of the metal into the die be greater than the cross sectional area of the sprue leading into the casting cavity and also greater than the cross sectional area of any section of the die? Referring again to the question of lubrication, that is, not in the "working in" period, but for application to the cavity faces during production, can our lecturer give us any other lubricant than the colloidal graphite already mentioned? The recommended quantity and the period of application would also be appreciated.

As to the question of the goose-neck type of die casting machine, where you have the goose neck coming up through the molten metal, is there any method of getting rid of the scum that will accumulate

on the surface ? Obviously each time the goose neck passes through the molten metal in the melting pot it picks up a certain amount of this scum and shoots it into the die, causing casting defects. Another point with regard to the goose neck machine, is it advisable to feed the metal to the melting pot, in a molten state, or is it quite in order to feed it as pre-cast ingots ? As to the question of die surface finish, do you recommend the highest possible finish that can be obtained such as an oil stoned or highly polished finish ?

MR. LAWETZKY : With regard to the length of the sprue, the sprue is divided in two parts, the part coming from the machine up to the die, and then the part to divide it from there into the die cavity. This latter one should be as short as possible. Place the castings as near together and as near to the sprue as you can. The limit to it is only so that you will have enough space to feed each of them separately. You have a certain distance between the cavities so the metal will not penetrate from one part forming a thin end. The sprue of the machine to the die is of big importance, and I found rather interestingly that the longer the sprue the better the casting. The reason for this I could not tell you.

Concerning the lubrication, especially for aluminium alloys, as I pointed out, cocoa butter is good. There is a mixture of colloidal graphite and fat which gives good results too. The best thing for these alloys still remains to be colloidal graphite, either in an oil solution or as I have recently heard, specially prepared in an adhesive solution to stick closely to the die. The people manufacturing these lubricants claim that after the die has been broken in it has not to be more often used than five or so times a day, sometimes even less.

The cross section of the entry is just the smallest possible. The screw should be conical coming in from the machine to the distribution place in the same cross section, and then the channels leading from the gate to the piece in an adequate section ; so, say, if you have got one gate, it should have exactly the same cross section throughout until it gets near to the casting, where it is throttled down, and at this position it takes the smallest size. The cross section at the gate in relation to the weight of the casting is not established. It is a matter of experience and depends upon the machine you use.

With regard to the goose-neck type of machine, concerning the slack coming into the goose neck. If you once clean the metal properly it does not form a slack for a long time as long as it is not overheated. If it forms then you have to pull it aside or maybe you have neutral atmosphere above the molten metal which prevents the access of air. This would prevent the accession of slack into the goose neck. Some goose-neck type of machines have got a valve

underneath so they do not take the top metal, but the metal from the bottom of the container, and in this the question does not arise at all.

With regard to the question of feeding with molten metal or with solid ingots, for zinc alloys the solid ingots are generally used to feed them into the goose-neck machine. In aluminium alloys the capacity of the machine in general is not sufficient to allow this and then you would not get the same temperature all the time, and for this I should recommend you to feed molten metal to the container.

For zinc castings it should be the highest finish possible. In the United States in some instances they do not polish at all. They take them from the machine exactly as they come out—so at least it was claimed. For aluminium and brass die castings just a polish finish is sufficient, since the die gets coated with oxide surface which is not very smooth itself, and so after a few shots anyway you do not get very smooth castings. Then you have only to place the sprue from the machine far enough, since starting from the sprue the heat cracks. In so far as these are removed, then the polishing does not give much more work.

A MEMBER : Could the lecturer tell us whether the temperature of the die has a detrimental or otherwise effect on the castings ? The temperature of the metal was mentioned but not die temperatures.

MR. LAWETZKY : With regard to die temperatures. The die is heated by the casting and is cooled down with water as I pointed out. The best method for a casting would be to raise the temperature of the die to the utmost. Unfortunately this is impossible since either the die would be destroyed too quickly or secondly, the casting, would not solidify quickly enough to keep up the production ratio. Therefore the die has to be cooled down just far enough to keep the die sufficiently cold to prevent the sticking of the metal to the die and to have the solidification of the casting wanted. To cool the die further is not to be advised.

MR. DIMARK : I would like the lecturer to tell us whether he knows of any experiments being conducted with the use of high grade modern cast iron for dies. I am particularly thinking of large die blocks which could be probably cast in a shape such as is used in the motor car industry for stamping dies and forming dies. I would like to know whether high grade alloy iron could not be used for die casting dies.

MR. LAWETZKY : As far as I know, experiments and tests have been made with cast iron generally, and some of them, especially for the low melting alloys have been successful. Whether these tests have been now performed with the new alloy cast iron I could not tell you. It is possible that they give good results, especially

in chilled castings, but no results have been found yet that I could give you, nor in any literature is there anything to be found.

A MEMBER: To take a typical die casting illustration to-night, a bib cock in base alloy, could the lecturer say how long the dies would last before they were seriously unconditioned ? Could he give us the information in relation to copper base and also how much longer they would last if they were heat treated ?

MR. LAWETZKY : It is a very important point to solve, this question as to heat treatment of the die and the supply of standard steel. Unfortunately die steel is not as I should call it standard quality. It differs a few fractions of a per cent. from the specification, and the carbon content especially is of much influence there. So you get with the one brand of steel with the same heat treatment sometimes a first class result and some times a rather bad one. The average die life of such a die as the bib cock to-day might be considered for copper base alloys as 25,000 castings. The very best results ever obtained are 83,000 from copper alloy castings. With zinc castings the die life is considerably higher and comes as a rule nearer 100,000 and sometimes over that. The highest figures which have been obtained I could not tell you. I think there are some dies which have not been used up yet since they were started.

MR. CROUCH : Could the lecturer advise which is the most suitable aluminium alloy used for castings in connection with pressure vessels, where you have a vessel under an air pressure or hydraulic pressure the whole time when in use, and would the same material be good for gravity castings ?

MR. LAWETZKY : The alloy with the closest grain I know is silumin as it is called in Germany. It is actually an alloy of silicon and aluminium containing 12.5% of silicon. If this alloy is cast at 750°C. it gets the closest grain and the best air pressure density which I have found yet. Another alloy which gives very good results, especially used in America, is 6% silicon and 3% copper. It has not as close a grain as silumin castings but is much easier to machine and easier to cast.

MR. CROUCH : Would this also apply to gravity castings ?

MR. LAWETZKY : For gravity castings silumin alloy is the very best possible. The higher the silicon content in the alloy the better the casting is. The copper content is just against this property.

MR. PUCKEY (Section President, who presided): As no one else wishes to put a question there is at least one I should like to ask our lecturer, and this may perhaps be rather an awkward one : how far, in his opinion, will the die casting process eventually disappear in favour of the cheaper plastic moulding process ?

MR. LAWETZKY : I do not know. I am a metal working man and I have everything to say against plastic moulding. There have been many trials in Germany to replace metal parts by plastic moulding.

In the electrical industry they have been successful. In most of the others plastic moulding has been tried and has been already abandoned. For instance, in the plumbing trades certain parts have been made which were formerly made in metal or in china from plastic moulding, and they have abandoned it. They use now instead of the formerly used copper base alloys, zinc alloys, or aluminium alloys, or they went back to the china. Only on account of insulation properties have plastic moulding pieces scored.

MR. GILES: We have listened this evening to an unusually interesting lecture on a subject which is a highly specialized one, and I am sure you will agree with me that our lecturer has dealt with the subject in a most able manner, and I should like you to join with me in an expression of appreciation.

MR. LAWETZKY: I thank you very much, gentlemen, for your kindness. I know the lecture has not been what I intended it to be. It has not given the enlightenment I wanted to give to you, but that is partly on account of not being too familiar with the language, and partly on account of being unfamiliar with lecturing. But if you are satisfied, nevertheless I thank you very much.

[By Courtesy of Machinery

Meeting of the Council, 36, Portman Square, London, December, 1937

Reading from left to right at the outer side of table are : C. A. Clarke, W. F. Dormer, J. R. Sinclair, R. C. Fenton, H. A. Drane, E. W. Hancock, J. H. Bingham, Lord Nuffield, Lord Sempill, R. Hazeleton, and T. Fraser. At the centre table, left side from front : F. Gorver, G. H. Hales, J. France, and J. G. Young. Right side from front, F. L. Daniels, Col. L. Sadler, E. J. H. Jones, F. W. Halliwell, and W. Marsden.

DIAMONDS IN INDUSTRY.

Paper presented to the Institution, Western Section, by A. H. Shaw.

I THANK you for the opportunity you have given me of speaking to you this evening on the part the industrial diamond plays in modern industry. You are chiefly concerned in the use of the diamond for many industrial purposes. I therefore purpose, first of all, dealing with this part of my subject.

Those of you who have used diamonds, especially since they have touched such high prices, must have had many anxious moments, for every user at some time or other has had trouble with diamonds. Diamonds may bring pleasure to the engineer's wife, but to the engineer diamonds often bring anxiety. I hope the paper I am reading will be the means of imparting information of a helpful nature, and will result in bringing down your diamond costs in many directions. If my address to the Production Engineers should not be profitable, let me hope you will be able to say " It has been interesting."

The diamonds you employ can be divided into four classes: (1) Carbon or carbonado; (2) ballas (both Brazilian and Cape); (3) Brazilian boarts; (4) Cape boarts.

Carbonado or Carbonate diamond was discovered in the Diamond Gravels of Brazil in 1842. Carbonate bears no resemblance to the diamond; it is found in irregularly shaped pieces with rough surfaces, which frequently contain minute cavities. It is dark brown to nearly black in colour, opaque and absolutely non-crystalline with an amorphous fracture; viewed with a magnifier it has the appearance of a piece of coke, hence, probably, its Spanish name " Carbonado." It is the hardest and toughest of all the diamonds when of first quality, and this quality is relatively rare and very costly.

The total output of a few years back amounted, yearly, to 30,000 carats, the sizes ranging from mere fragments up to stones of about 500 carats. Before the year 1870 when Diamond Rock Drilling was unknown, the price was no higher than 1s. per carat; to-day you would have to pay £20 per carat for the finest specimens.

Carbon is treacherous material, the best judges are sometimes deceived. I have seen carbons ground away almost as easily as chalk. The judging of quality is a difficult thing which demands

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Bristol, October, 15, 1937.

great knowledge, and even with many years of experience, errors are possible. Stones are sometimes judged by their specific gravity. This test is not infallible. Carbons that have passed this test have proved soft in use. However, it is quite a prudent course to reject stones of a low specific gravity.

It is a wise course to buy broken carbons. The structure of the stone can be seen, and the split side has the appearance of broken steel, is not porous, and most minute crystals can be seen, such carbons will not let you down, though their price may give you a shock.

Ballas is round in form, and possesses a radiated internal structure, hence the collected crystals have a radial instead of the octahedreal fracture of the diamond. True ballas is rare. The hardness of the Brazilian Ballas is very great, equal to that of the very finest carbons, hence it commands almost the same price. Ballas diamonds are also found in South Africa. These are not reputed to be as har d as the Brazilian stones, but in the case of the very fine specimens I do not think there is much difference. They are cheaper in price and, if cost is taken into consideration, they are, n my opinion, quite as satisfactory.

Where diamonds are subjected to severe usage on large wheels, and particular attention is paid to the proper use of diamonds, ballas can be recommended.

Brazilian Boarts. All I am about to say of Cape Boarts can be said of Brazilian boarts. There is this in addition compared to South African, the Brazilian diamond is reputed to be harder but it is more brittle and dearer. "The Gods seldom give with both hands."

Grey and Brown Cape Boarts. It has been estimated that approximately 85% of the industrial diamonds used for industrial purposes consists of grey and brown Cape boarts, which should indicate that they give good service. In this general description are embraced the Premier, Jagersfontein, Wesselton, Bultfontein, West African, Angola, and Alluvial, these descriptions being the names of the mines in which the diamonds were found. Some of these mines have beeen temporarily closed. Unfortunately the practice of the Diamond Corporation to mix diamonds from various mines makes it almost impossible to definitely determine the mine origin of some stones.

The opinion generally prevails that every boart diamond is imperfect. That may, to some extent, be misleading. Diamonds are mined primarily for the production of gems, but a large proportion of the stones are unsuitable for this purpose, for the following reasons :—

(1) Some diamond have cross grain or ballas formations and are, therefore, too hard to polish.

(2) Some diamonds contain a number of black carbon spots which would be imperfections in gems.

(3) Diamonds of a brown, grey, black, or cloudy-white appearance are of little value as gems.

All the above classifications are sorted from those suited for gems, and are used for mechanical purposes.

The finest grades of these rejections are recommended for various industrial uses. A very close study of the various colours of diamonds has generally proved that the grey, black, or white stones are harder than the various shades of brown. This, however, does not mean that such stones, because of their hardness alone, are superior to the brown stones.

Although the grey, white, and black stones may be harder than the brown, we must not overlook the fact that with their hardness they are also more brittle. If it can be said of the brown stones that they are relatively soft, it should be remembered :—

(1) They are sufficiently hard to withstand reasonable wear.

(2) They are not so brittle as grey and white stones.

(3) Diamonds may be very easily ruined by careless use, and brown diamonds will stand more abuse without breaking than any other class of boart.

From the foregoing remarks you will see that personally I do not pay much heed to the colour of a stone; neither need you, but you would be wise to select diamonds free of flaws and fractures. To do this, the greatest care must be exercised, for the clean sound stones form but a small percentage of the diamonds sold for industrial use. For such stones you must be prepared to pay fair prices ; in the end they will be found to be much cheaper than the lower priced material which unfortunately abounds to-day.

In comparing offers do not content yourselves with the mere comparison of prices, which will not give you a true indication of the values offered. Some diamond dealers may be wrong in describing the quality of their goods, of course quite unintentionally. Ask to see the goods the competing houses purpose supplying, and make your selection, always remembering to choose a sound stone, irrespective of colour or shape. An honest dealer will help you, for such does exist.

Do not use a small diamond to dress large wheels. I have heard of a $\frac{3}{4}$ carat stone being used to dress a 40 in. wheel. Think of all the announcements grinding wheel manufacturers make as to the hardness of the grit and bond of their wheels and picture a massive wheel making 2,000 or is it 4,000 revolutions per minute ! Too much

is expected if you think a poor little ¾ carat stone will stand up to such work indefinitely.

If a diamond should crack up do not think your merchant has wilfully let you down. Diamonds can play strange pranks. They are a product of nature, their composition and temper are placed beyond human control. The late Sir William Crooks, no mean authority, wrote as follows :—

"I have examined many hundred diamond crystals under polarised light, and with few exceptions the colours show how great is the strain to which some of them are exposed. On rotating the polariser, the black cross most frequently seen revolves round a particular point in the inside of the crystals. On examining this point with a high power magnifier we sometimes see a slight flaw, more rarely a minute cavity. This cavity is filled with gas at enormous pressure, and the strain is set up in the stone by the effort of the gas to escape. I have already said that the great Cullinan diamond by this means revealed a state of considerable internal stress and strain. So great is this strain of internal tension that it is not uncommon for a diamond to explode, soon after it reaches the surface, and some have been known to burst in the pockets of the miners or when held in the warm hand. Large crystals are more liable to burst than smaller pieces. Valuable stones have been destroyed in this way, and it is whispered that cunning dealers are not averse to allowing responsible clients to handle or carry in their warm pockets large crystals fresh from the mine. By way of safeguard against explosion some dealers imbed large diamonds in raw potato to ensure safe transit to England.

Suggestion for your Grinder Operators on the Correct Use of Diamonds when Dressing Wheels.

The following suggestion should help to obtain more efficient as well as more economical results among consumers : (1) Take light cuts with the diamond ; (2) As the diamond wears, turn it in the holder to assure uniform wear ; (3) When the stone wears down to the metal setting be sure to reset the stone so as to expose a new cutting surface ; (4) When the diamond is worn down to a small size, reset it and mark for tool room use ; (5) Instruct operators to be careful about giving the diamond any hard knocks. The stones are very hard and for that reason rather brittle ; (6) Be careful not to jam the diamond into the wheel ; (7) Never use a diamond dry except perhaps on small wheels for internal grinding or on tool and cutter wheels ; (8) On large wheels for cylindrical or surface grinding use a copious stream of water and direct it on the diamond at its point of contact with the wheel ; (9) Give each operator a diamond, careless users can be better traced.

When a pronounced flat is worn on a stone, if it is kept in use it will be in a state of incandescence, and disintegration is almost bound to set in. It is a mistake to think the diamond merchant likes to see your diamonds break up and your diamond costs mount up, for he is genuinely interested in keeping down the cost of dressing grinding wheels. An account can be retained when the cost of the diamonds is not excessive in relation to the work done.

The great cause of diamonds breaking up is their continued use after they are worn down almost to the setting. The continued use of a diamond when only a broad flat is presented to the wheel means taking the risk of the diamond breaking up. We are tired of telling some users to have their diamonds more frequently reset.

There are some firms who seem to be able to break up any diamond, always the firms who neglect to have the diamonds reset frequently. On the other hand, it is in those shops where frequent inspection of the diamonds takes place, where records are kept, where resetting is frequently done, that diamonds are used economically and the number of breakages is brought down to the minimum, indeed, a breakage only occurring when the stone is worn down to a relatively small size.

What I have said is not the only advice which has been given to grinding operatives. The humourist has been at work. Here is an extract from an old copy of " Abrasive Industry ": " Always be sure to give the diamond a hard blow against the grinding wheel when beginning a truing operation, thereby making sure that the stone is tight in its holder. Never use water when truing the wheel as you might get wet and the absence of water will help to turn the diamond into a nice little piece of silicate ash. Don't put any faith in the diamond dealer who tells you that a diamond can be burned, as a lighted match has no effect on it. If the stone in a diamond truing tool is loose, don't tell the boss about it—he will be peeved. Drive the stone in place with a hammer; if it breaks knock out the pieces and substitute a piece of lead taken from a carpenter's pencil. Turn the tool into the tool-store and get your check." There is many a true word spoken in jest.

One is often asked what weight of diamond should be employed in dressing a wheel of given size. In this matter I think you should seek the advice of users of varied experience who have service records of diamonds extending over long periods, and who have no interest in sending up your diamond costs, but indeed, who are interested in keeping them down.

The Norton Co. believe that the following list is in accordance with present practice :—

Diameter of wheel in inches	Stone size in carats.
6	$\frac{1}{2}$
8	$\frac{3}{4}$
12	1
14	$1\frac{1}{4}$
18	$1\frac{1}{2}$
24	2
30	$2\frac{1}{2}$
36	3 to 5
46	5 to 9

Setting.

If you want to secure good service from a diamond it must be set securely, and set to its best advantage. It is better to leave this work to the expert. Our method of setting, finally adopted after many experiments, is the well-known brazing process. It is simple, quickly done and is efficient. The many friends for whom we do this work will bear out our statement that they are not troubled by diamonds becoming loose.

A hole is drilled, size and depth having relation to the size of the diamond ; the end of the holder is slit into quarters, the prongs thus formed are pressed on to the diamond. We have our own method of doing this, and even at this stage the diamond is held securely, but the tool is then brazed. There are other ways of setting diamonds, viz., to peen the stone in copper or mild steel rod. With this method care must be exercised—give a light tap on a diamond on the plane of cleavage and it will split. There is also the casting method, in which bronze, Monel metal and copper may be used. These methods of casting are rather complicated and great care must be exercised.

The variety of work for which the diamond is suitable is well appreciated by manufacturers. Besides the use of diamonds as emery wheel dressers, there are many applications for diamonds in modern industry. The modern manufacturer has been convinced that by substituting a diamond cutting tool for a steel one he can considerably reduce his operating expenses. He now appreciates the economies which diamond tools have made possible. For finish machining on bronze and non-ferrous metals, the diamond is especially suitable on account of its ability to retain its cutting edge when producing great quantities of parts without frequent attention or resetting up.

Work which has a uniform diameter over a considerable length such as the brass sliding tube of a telescope, is successfully turned out by the use of diamonds, and without the slightest perceptible variation in diameter occurring in tens of thousands of parts. Diamond tools

may also eliminate some operations which must be performed when a steel tool is used.

The surface produced on brass and bronze with a diamond is comparable to a fine lapped finish, and, therefore, eliminates the necessity of reaming, finish-boring, grinding or lapping, to obtain the desired surface. It will be seen that the variety of work to which the diamond tool can be applied is very extensive. Its use for machining iron and steel is not practical, as these metals are likely to cause the brittle diamond to crack or chip.

The use of diamonds for turning long cylindrical parts, which must have a uniformed diameter throughout, has previously been referred to, and one instance of this application is that of turning brass sliding tubes of telescopes. Telescopes tube are often several feet in length, and present a condition which, by the use of steel turning tools, caused considerable trouble in maintaining a uniform diameter throughout.

The diamond tools of which I have just been speaking are shaped and polished by a similar process as is employed in polishing a brilliant, but the diamond polisher has to be trained for this special work.

Given good material and favourable working conditions a good diamond tool should not chip, but only periodically require polishing. Chipping of diamond tools is usually due to one of the three following reasons: (1) Insecure mounting in the machine, or an unsuitable machine; (2) flaws in the diamond; (3) the cutting edge of the diamond becoming dull after prolonged use, therefore, requiring too much pressure in use. The pieces of material are thus torn off, straining the cutting edge of the diamond.

Thanks to several machine tool manufacturers, who have introduced special machines for fine boring and turning operations, it is the recognised practice to-day to turn pistons, bore gudgeon pin holes, bore both ends of connecting rods and also in some instances bore out white metal bearings in crank cases, with diamonds. One Continental concern, building specialised Aero Engines, is running eight of our tools in one boring bar for boring the crank case. This will show you how the automobile and aero engineers have taken up the use of shaped diamonds wherever they possibly can.

The application of the diamond mounted in rings or crowns for boring originated with M. J. Rudolph Lescot, a French Engineer, in 1862, and the system adopted by that gentleman has remained virtually unaltered. A crown is a circular tube of mild steel in which is inserted eight to four or five hundred diamonds, some on the outer edge, some on the inner, others in a mid position, so that nothing but diamond comes into contact with the rock. This crown is slowly propelled, as it sinks, and a core occupies the centre.

The drill is taken up from time to time, tongs are sent down to grip the core, which after being broken off at its base is brought to the surface. The mystery of what was below is solved.

Diamond Crown Drills vary from 2 to 24 inches, external diameter. They are driven by powerful machinery to depths which range from 500 for the smallest to over 2,000 feet for the largest, and they bore through all stratifications, cutting or grinding their way through granite, tunnelling and for other rock boring on land or under water. These vertical diamond drilled holes are frequently made to very considerable depths. There are several which exceed 4,000 feet and one made in search of coal at Schladeback in Prussia has accomplished 5,736 feet, or the amazing depth of more than one mile.

Truly there is nothing new under the sun, (I have just mentioned and rightly so, "The application of the diamond mounted in rings or crowns for boring") for there is little doubt that the applications of the diamond as a tool, are revivals, although frequently ramifications, of its similar use in the remote ages.

The following particulars taken from a paper contributed by Professor W. M. Flinders Petrie, to the journal of a learned society, 1883, refer to the date 2400 B.C.

"The principal result of the examination of these remains is the discovery that the stone cutting was performed by graving points far harder than the material to be cut, and that, as the stones operated upon were quartz or mixtures containing quartz, the graving point must have been, therefore, of some jewel harder than quartz, since no metal, not even the hardest tempered steel, is capable of cutting quartz apart from a mere bruising action. These cutting points are found to have been embedded in a basis of bronze, in order to hold them in the right position and to move them with the required force."

Professor Petrie considers it proved that diamonds or other hard gems were mounted on the edges of saw blades, and that the holes and solid cores proved the use of numerous sized tube drills, and almost as certainly that of the diamond itself. This last point has not as yet positively been determined, but both cores and holes all show irregular spiral markings and other characteristics which result from the use of the modern diamond tube drill.

The making of Diamond Dies for wire drawing is a work that requires a great deal of care. The rough diamonds are set into brass die holders, and temporarily held by means of shellac while a conical centre for the drawing holes is being cut. The diamond is then brazed in the die holder. The surface of the brass holder is then ground to smooth off the brazing, so that the die will present a flat surface from which it may be located on the surface plate of a lathe while the drawing hole is being made. This ensures that the hole will be square with the face of the die holder.

The diamond die is centred on the face plate to which it is held by shellac. The tool to produce the hole or channel is a common sewing needle. The needle is chucked in the end of a tool holder and supported in the tail stock. The needle is charged with a thin paste of diamond dust and oil, the diamond is revolved, a reciprocating movement is imparted to the tool holder, which moves the needle in and out of the hole that is being produced in the die. The hole produced by the needle is tapered, and enlarged at both ends to a slight curve. The wire to be drawn is passed through from the large end of this hole and the diameter at the small end governs the finished size of the wire, and must be held to within limits of a tenth of a thou., of the required size. Many tons of wire can be drawn through these dies before any appreciable variation in size is noted.

The anxiety of a poor maker of these essential tools you can imagine when I relate my own experience. I was trying to interest one of the largest electrical lamp manufacturers in our dies, the hole of which was much smaller than a hair from your head. Before the purchase was effected the dies were examined in the laboratory, a microscrope was called into use, and the minute hole was scrutinised. In one instance the report was as follows: "The entrance not of good shape. The channel not sufficiently polished and not perfectly cylindrical. The exit badly formed."

I am indeed thankful that I am not personally engaged in producing work for so critical a judge. I am sometimes tempted to think that technical institutes which produce such dreadfully clever young critics are not unmixed blessings.

Hardness Testers. The hardness of modern steels could not be so correctly ascertained without the help of the diamond. There are a number of hardness testing machines on the market to-day which incorporate the diamond. We have made many thousands of points for these machines.

There are several types of diamond indenters—cone, pyramid, and spherical. We supply these diamonds to the actual makers of the machines and I need hardly say that our work is most exhaustively scrutinised—not merely as regards the quality of the diamond but the accuracy of the angles we have worked up. One has always to be on the "qui vive" when it is known that the work has to pass through a laboratory for examination before acceptance. Needless to say, diamonds used for this work have to be of exceedingly fine quality. We have seen many diamonds in cheap rings which are far inferior in quality and colour to the stones we use for this particular purpose.

Another recent application of the diamond is the cutting of very fine lines on aluminium discs. I received a surprise when I visited the London Zoo. I was asked to make a record of my own voice, and after delivering my oration I was presented with an aluminium

disc which being placed on a gramophone, reproduced my voice. On looking at the machine I was surprised to see that the records were made by special diamond points which our concern had supplied to the makers of the machine. These are small diamonds, accurately lapped to specification, very small limits being allowed. A similar diamond is used for various engraving purposes, such as on copper plates, bank notes, steel rules, and cotton printers' rolls.

Many wrong impressions exist regarding the glaziers' diamond. I should like to give you a little information concerning this useful tool. A glaziers' diamond is a specially selected stone, preferably a perfect octahedron. This is carefully mounted so that when held at a certain angle a smooth edge comes into contact with the glass, not the point alone of the diamond but a perfect smooth angle. The smooth diamond glides over the even surface of the glass, the weight of the hand lightly presses the diamond into the surface and the molecules are gently separated. Where this surface separation is made the glass will easily break.

I was in a window glass factory the other day and I was indeed astounded to see how lightly the diamond was skimming over large sheets of glass. The mark made by the diamond was barely to be discerned on looking at the surface, but a brightline was seen on looking through the glass. Where this light contact had been made the glass was readily broken.

The glaziers' diamond is not used for cutting all kinds of glass. It would be useless for cutting glass with very rough surfaces, unworked optical glass for instance, but the diamond in another form will cut up this material. A thin disc of mild steel about $^1/_{16}$ in. thick, is propelled at a high rate of speed, the periphery is charged with diamond dust or diamond splint, and the glass is sliced up to the size and shape needed. By the way, diamonds themselves are sawn up in like manner if it is found more advantageous than cleaving.

There is still another kind of diamond saw that is employed for sawing stone. An up-to-date stone yard has its power driven diamond circular saw. In the outer circumference of the saw, in place of the teeth, sockets are inserted in which diamonds are embedded. The diamonds are arranged in the saw, some on the right, others on the left, the remainder in the centre ; the diamonds alone coming into contact with the material being sawn. Marble, Portland, and other stone is thus cut with great rapidity and small loss of material.

In the United States, diamond dust is used to a much greater extents than in England, in the lapping of gauges and for the finish grinding of parts of small precision machine tools. The grades of

diamond dust used for charging laps are designated by numbers, the fineness of the dust increasing as the numbers increase. The diamond, after being crushed to powder in a mortar, is thoroughly mixed with high grade olive oil. This mixture is allowed to stand for five minutes and then the oil is poured into another receptacle. The coarse sediment which is left is removed and labelled No. 0, according to one system. The oil poured from No. 0 is again stirred and allowed to stand for ten minutes, after which it is poured into another receptacle and the sediment remaining is labelled No. 1. This operation is repeated until practically all of the dust has been recovered from the oil. The No. 0, or coarse diamond, which is obtained from the first settling, is usually washed in benzine, and recrushed unless very coarse dust is required.

With the introduction of tungsten carbide tools came the thought that perhaps a tool had arrived for fine turning which would supersede the diamond, but we are happy to say that after tests the diamond is still proved to be the most effective means of taking light cuts on non-ferrous material.

The Tungsten carbide tool has, however, made wonderful advances in other branches of engineering, but it often requires fine lapping. When this happens the diamond comes to its aid for when diamond dust is incorporated in bonded wheels or applied to a cast-iron disc, one can obtain a beautifully lapped tungsten carbide tool, whereas before the only method of sharpening these tools was on special grinding wheels. This method was very laborious and when finally completed was usually far inferior to what one would desire.

I could go on for a longer time than you would wish in speaking of the varied use to which the diamond in some form or other is used, but I must conclude. My mentioning the word "time" causes me to think of a watch ; the diamond has pierced and shaped the jewels forming the bearings of the wheels. It has cut the glass ; shaped diamonds have turned the gold case and engine turned the back.

Our business brings us in touch with many of the greatest manufacturing concerns of the world, but side by side with such accounts as these are transactions with very useful and humble members of the community—the travelling tinker or china rivetter, who asks to be furnished with a diamond for 1s. 6d., and is supplied. The china rivetter slits the end of a wire nail, puts his diamond in the slot, presses the sides together and then gets along with his job. The diamond may hold in whilst many shallow holes are drilled and when it falls out he resets it. A wire nail, a piece of umbrella rib, or a cone made out of a piece of tin, such are the mounts the china rivetter favours.

In future when diamonds are mentioned, do not merely regard them as the flashing gems you love to, and persist in, showering upon your women folk. The diamond plays a worthy part in our industrial life. From tunnelling a mountain range, to mending a broken tea cup, it is ever at your service.

Discussion.

Mr. Perks: Can the shapes of the diamonds be altered by the user, and if so, how? Secondly, what is the relationship of the diamond tool to the Wimet tool on intermittent cutting? Can we have any particulars of the life or resistance of the diamonds for this type of cutting? Thirdly, Mr. Shaw mentioned in his paper that you reset your diamonds by brazing. Is this not a costly job?

Mr. Schneider: The price of resetting an ordinary turning tool, that is an ordinary wheel dressing tool, is 3s. 6d., but supplying with a new base of steel, re-sharpening and/or resetting a shaped diamond tool the cost is 21s. That, of course, entails the use of a different machine altogether, and the diamond has to be taken from its holder. It would probably take from two days to a week, and it might take as long as a month for resetting. We only recommend the diamond tool for finishing cuts. The Wimet tool cannot compete with the diamond for the finish and long life of the cutting edge. You would have to reset the machine more frequently than with a diamond and you would not get the same finish.

Regarding the question of whether it is possible to alter the cutting edge of the diamond in the user's shop, you must understand it is a specialist's job. They are polished in exactly the same way as a diamond ring is polished. There is no secret in the job. It is placed on a diamond wheel aproximately 9 in. diameter, rotating at a speed of 2,500 revs. per minute. Before we go any further, you must understand that diamonds are similar to wood (if you examine them closely you can see the grain) and if you place a diamond on the wrong direction and leave it there, nothing will happen. Placed in the correct position the diamond will polish. We do not recommend anyone to polish their own diamonds. Although in engineering I know you work at certain shearing angles, etc., it does not necessarily mean the same with a diamond. With a diamond the maximum cut is .003 in. to .005 in.

Mr. Crombie: Can you explain why one should use such a large diamond on a wheel grinding tool as recommended by The Norton Co.? For instance, on a 46 in. wheel a 5 carat diamond is recommended. I do not think I have yet experienced a firm using one of this carat. Multiple diamond tools were, I believe, developed in America. Do you consider them to be better than similar tools developed, and now being produced, in this country? Are these tools suitable for use with large wheels?

Mr. Schneider. The tool was developed in America, but remember that 95% of the diamonds mined in the world come to London and are resold to America, so that you can see that the diamonds

sent to America are the same as used here (I won't say ours are better). The diamonds on this type of machine are long sausage shaped, and you cannot grind large flats on them.

MR. CROMBIE: The average multiple tool contains five diamonds. Do you recommend small diamonds?

MR. SCHNEIDER: We have some customers who will not look at a single stone, and others who won't look at multiple tools.

MR. MAURICE: Mr. Shaw mentioned in his paper it was only advisable to use dry diamonds on small wheels. What is the position as regards small surface grinders? For instance, one or two, such as Browne & Sharpe's are arranged for dry grinding only and use a wheel 8 in. to 9 in. diameter by 1 in. What is one to do?

MR. SCHNEIDER: No diamond should be used dry, definitely, but some machines with small wheels, say 6 in. wheels, that are supplied with cooling apparatus, may be used dry. Of course, a 10 in. wheel is quite small and if you are not too heavy with the cut you should be able to use it dry, providing you can use a coolant (either air or suction). The object of the coolant is to keep the diamond from getting hot. Once it gets red-hot it is likely to break up. We have had tools come in where the holder has turned blue while in use.

MR. DANIELS (Section President, who presided): You would recommend a coolant for small internal grinders?

MR. SCHNEIDER: Certainly, if possible.

MR. CROMBIE: I was interested in the method of cutting diamond dies. Do you cut the holes right through the centre of the diamond?

MR. SCHNEIDER: The diamond is flattened in the first place either by cutting or polishing, and it is then put on the face-plate of a small lathe, and the centre is turned, and centralising the back turned again on the other side, then the diamond is revolved and pierced with a needle and diamond powder. Eventually it breaks through. The operation takes about two hours. One fourth of the actual diamond is drilled.

MR. CROMBIE: Do you use dies for drawing Stainless Steel Wire?

MR. SCHNEIDER: Yes.

MR. CROMBIE: What is the smallest size they draw?

MR. SCHNEIDER: Half-a-thousandth. Most of the small dies are for big electric lamp people, who make their own dies.

MR. DANIELS: Is the diamond used by cellulose manufacturers? They use some incredibly fine dies.

MR. SCHNEIDER: Yes.

MR. DAUNCEY: Mr. Shaw mentioned in his paper the machining of tubes and telescopes. Would you recommend diamonds for use on the ordinary machine tool working on small components such as brass bushes, screws, etc.?

MR. SCHNEIDER : Diamond Tools are only recommended for finishing cuts, they should not be used for any other operation. Years ago engineers who used diamonds, used the old type of lathe, with disastrous results. Then one or two machine manufacturers made a special machine for using diamond tools. Diamond tools are used by many of the big firms in this district, including B.A.C. and Parnalls.

MR. DANIELS : In preparing your diamonds, I suppose you do a quantity together ?

MR. SCHNEIDER : When we are polishing diamonds the most is six diamonds at once, at the beginning. When finishing we do only one at a time, and we have an instance of a diamond being put to the back of the mill for a month for polishing.

MR. WRIGHT : What cutting speed is recommended for diamonds on aluminium ?

MR. SCHNEIDER : Well, of course, we are diamond manufacturers and not users, but I think if you take the advice of a diamond user, he will recommend up to 4,000 ft. a minute for aluminium, 3 to 4 thousandth depth of cut on special machines.